SUSTAINABILITY STUDY FOR WHEAT STRAW TORREFACTION TECHNOLOGY

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Absract
The aim of this article is to examine the torrefaction production technology placed in two power plant environment (Rankine-Clausius, and Organic Rankine-Clausius circular procedures). The torrefaction is a heat treatment process at 280 – 300 °C obturated from oxygen, this heat treatment effectively changing the structure of the material, and the feedstock's heating value improves. Our study is restricted is wheat pallet because we conducted the laboratory experiments with material. In Hungary the agricultural industry produces raw materials in big amounts (mainly combustibles that is energetically renewables) which are at the moment, mixed with nitrogen-based fertilizers and biodegradable anaerobe bacteria ploughed back into the tillage as a form of nutrient supply. It takes 9 months to become nutriment from this inorganic material.
The object of our study is the key equipment of a production technology which continuously works, double-jacketed, and can be subjected to vacuuming. This equipment is a cylindrical furnace in which the torrefaction is realized.

Keywords: *biomass, heat treatment, power plant, torrefaction wheat straw*

1. ABOUT THE TORREFACTION PROCESS

The torrefaction is a three-stepped heat treatment technology: a heating, a torrefaction and a cooling section included. Inside of the reactor the moisture content evaporates in the first place, when the biomass reaches the 200 °C the physically bounded water is released. When the temperature reaches the 280°C the de-polymerization of the hemi-cellulose occurs. The torrefaction frees the water, the volatile organic compounds, and the hemicellulose from the cellulose and lignin.

With all of the polymers involved the dehydration process takes place, it destroys the "OH" groups that are responsible for H_2 that binds the water. This reaction limits the ability to absorb water into the torrefied material [1]. This is a significant feature of the torrefied material because of its undemanding storing needs. It is possible to store the produced materials under the sky without an expensive storage building.

2. ANALYSIS OF THE THEORETICAL REACHABLE HEAT RADIATION POWER

We want to create clear radiation inside of a furnace, which is not possible because of the surface contact of the cylindrical shell of the bale with the surface of the furnace. During our investigation we do not take into account the heat transfer and heat conduction, as a result we are investigating a process which is that good from the thermodynamic perspective. The heat source is only the cylindrical shell of the furnace. The heat transfer with heat-radiation we can analyze with the following formula:

$$Q = A \cdot \varepsilon \cdot \sigma \cdot F_{1-2}({T_2}^4 - {T_1}^4) \tag{1}[2]$$

where,
A: absorbing area [m^2],
ε: emissivity coefficient, wheat straw 0,91[2],
σ: Stefan-Boltzmann constant, [$W/(m^2 \cdot K^4)$].
F_{1-2}: view-factor,
T_2: temperature of the heat source, here 300°C,
T_1: temperature of the absorber, here 20°C.
The view-factor can be determined with the following formula:

$$F_{1-2} = \frac{1}{\pi R_2}\left[\begin{array}{l} \frac{1}{2}\left(R_2^2 - R_1^2 - 1\right)\cos^{-1}\frac{R_1}{R_2} + \pi R_1 - \frac{\pi}{2}AB \\ -2R_1\tan^{-1}\left(R_2^2 - R_1^2\right)^{1/2} + \left\{\left(1+A^2\right)\left(1+B^2\right)\right\}^{1/2}\tan^{-1}\left\{\frac{\left(1+A^2\right)B}{\left(1+B^2\right)A}\right\}^{1/2} \end{array}\right] \tag{2}[3]$$

Within this formula we can find the following variables: ratio of the radiuses and the height, and the two cyclinder's radiuses can be analyzed from the following draft's marking:

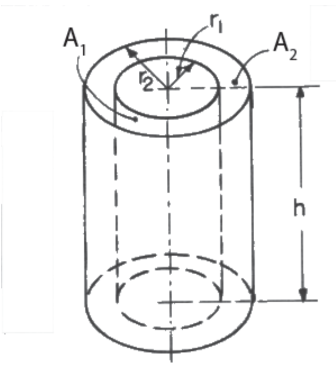

Figure 6. The marking belonging to the furnace and the bale

$$R_1 = \frac{r_1}{h} \tag{3}[3]$$

$$R_2 = \frac{r_2}{h} \tag{4}[3]$$

$$A = R_2 + R_1 \tag{5}[3]$$
$$B = R_2 - R_1 \tag{6}[3]$$

Its value is 0.9844. To define it, the diagram in literature [2] can be helpful.

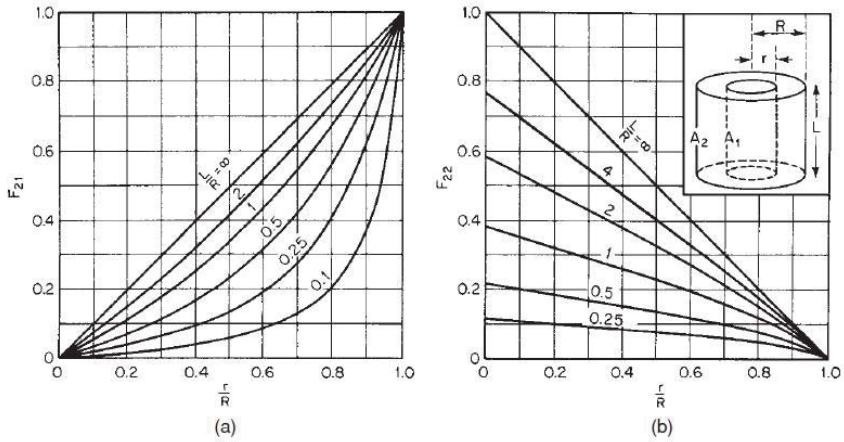

Figure 7. Choosing the view factor on the basis of the diagram [2]

With the application of the above mentioned guidelines we defined heat relations in the different h/d relational, but in volume equal furnaces. Our aim was to examine in every single h/d relationally different furnaces the same weight. 1 m^3 volume furnace can handle 90 kg wheat, while 10 m^3 furnace can handle 900 kg wheat.

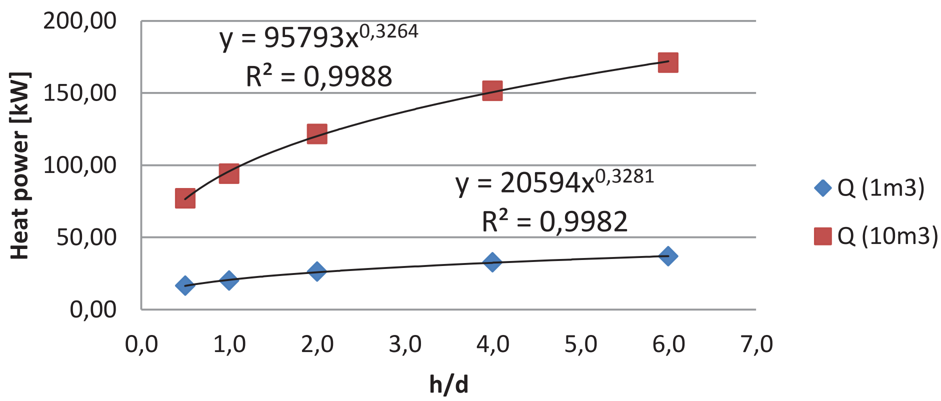

Figure 8. The theoretical reachable heat radiation flow in the 1, and 10 m3 furnace

On the Figure 3. what we can get out from the system with such temperature and material characteristics.

3. DETERMINATION OF THE ENERGY DEMAND OF THE TORREFACTION

To heat up the given amount of the straw we need to input the following energy:

$$Q = \dot{m} \cdot \mathrm{c} \cdot (T_2 - T_1) = 90\,\frac{\mathrm{kg}}{\mathrm{h}} \cdot 1{,}7\,\frac{kJ}{kgK} \cdot (300 - 20°C) = 11{,}9kW \qquad (7)[4]$$

It seems like we miss the energy demand of the reaction, because this is an endotherm reaction, but we lose mass during the process so we assume the energy demand according to the [1] literature.

$$Q = \dot{m} \cdot \mathrm{c} \cdot (T_2 - T_1) = 900 \frac{\mathrm{kg}}{\mathrm{h}} \cdot 1{,}7 \frac{kJ}{kgK} \cdot (300 - 20°C) = 119\ kW \qquad (8)[4]$$

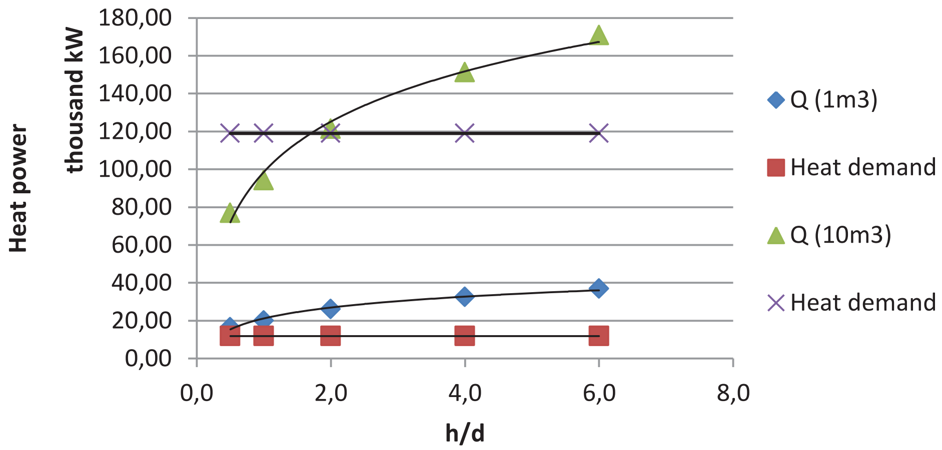

Figure 9. The heat power demand of the wheat straw for torrefaction fitted into the Figure 3.

4. CONCLUSIONS

According to our analysis of the scale-up of the torrefaction furnace has some difficulties occurred by the heat power demand. If we want to treat for example 900 kg of basic material, the shape and the h/d ratio of the furnace are very important. If we choose h/d ratio below 2 we will have heat transfer problems. In the future we should examine the heat transfer relations, we should determine the heat transfer coefficients, and choose the proper heat transfer fluid.

5. ACKNOWLEDGEMENT

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