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THE EFFICIENCY OF BIOGAS TECHNOLOGY: A CASE STUDY

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Abstract: *The paper presents a case study regarding the efficiency appliance of biogas technology at the Agronad SME, a private firm which produces alcohol from grain in Romania.*
Key words: *case, biogas, power, economical*

1. INTRODUCTION

Any new unit for biogas production is always welcomed, especially when alcohol is used. The reactor uses the anaerobic digestion method to obtain bio-methane which leaves week pollutant compounds after burning.

Organic waste is also reduced and processed to obtain good materials for agriculture. The biogas reactor and the gasholder are placed close to the reservoir with mixture resulted from alcohol production. The final calculus shows how the biogas production raises the efficiency of the Agronad SME.

2. BRIEF PRESENTATION OF THE DISTILLERY

The next images presents the location of the biogas plant in the general landscape of the Agronad SME and the gravitational circulation of the mixture to the biogas reactor, the storage of the bio-methane and the final use of the biogas. The scheme is very simple and uses few compounds. So, final efficiency is increased (*** research grant, 2007).

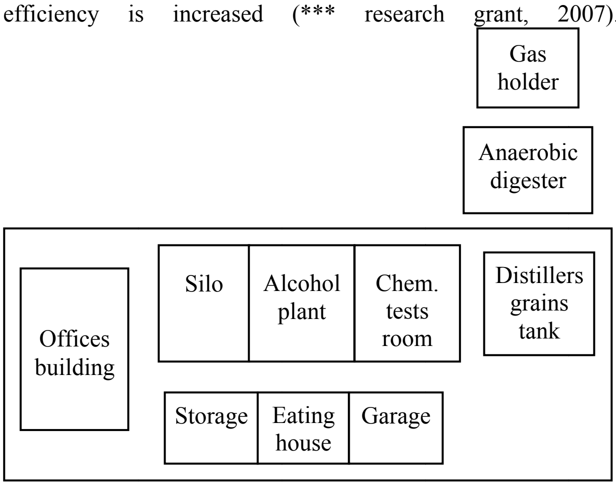

Fig. 1. General landscape and biogas plant layout

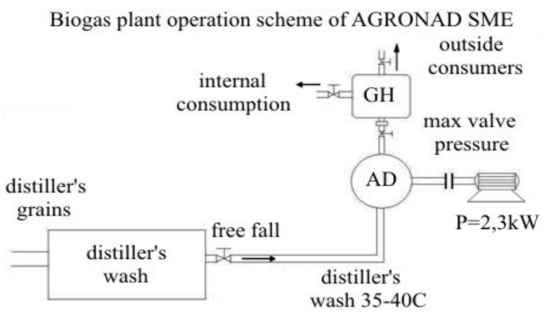

Fig. 2. Biogas plant operation scheme

3. ESTABLISH OF ENERGY CONSUMPTIONS

3.1 Calculus in area I

This area is situated between the two cylinders, first of radius R_1 which corresponds with the propeller diameter and the other one of radius R_2 which corresponds to the interior diameter of the tank, according with Fig. 3. (Baran, 2008).

R_1 = 0,5 m, R_2 = 1,68 m and the volume has the height: $L = h_1 + h_2 = 1,73 + 0,48 = 2,21m$.

Distillers wash from corn which fills the reactor has the dynamic viscosity η=1,19*10^{-3} Ns/m^2 and the density ρ=1006,85 kg/m^3, for a temperature of 16°C (Stroade, 2010).

The momentum of viscous friction is computed in each of the two previous areas and then the total momentum is obtained.

For area I a linear distribution of the speed is admitted inside the distillers wash from corn.

$V = \omega R_1$ on the cylindrical surface situated at the extremity of the propeller and $V = 0$ on the interior wall of radius R_2 of the reactor, in accordance with the adhesion property of the viscous fluids.

The tangential effort on the cylindrical vertical surface of radius R_1 is:

$$\tau = \eta \frac{V - 0}{R_2 - R_1} = \eta \frac{\omega R_1}{R_2 - R_1} \quad (1)$$

This effort is active on the surface: $S = 2\pi R_1 L$

The viscous friction force becomes:

$$F = \tau S = \eta \frac{\omega R_1}{R_2 - R_1} 2\pi R_1 L = 2\pi \frac{\eta \omega R_1^2 L}{R_2 - R_1} \quad (2)$$

The necessary power to rotate the liquid is:

$$P = FV = 2\pi \frac{\eta \omega R_1^2 L}{R_2 - R_1} \omega R_1 = 2\pi \frac{\eta \omega^2 R_1^3 L}{R_2 - R_1} \quad (3)$$

3.2 Calculus in area II

This area include the upper cylinder of height h_1=1,73m and the bottom cylinder of height h_2=0,48 m, which are placed above and under the propeller.

The tangential speed of the fluid layers situated in the vicinity of the propeller (upper and bottom layers) is variable with the radius $r \in [0, R_1]$: $V = \omega r$

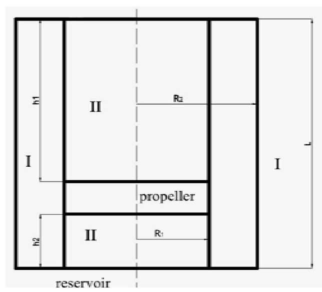

Fig.3. Simplified scheme of the reservoir

It depends of the radius $r \in [0, R_1]$: $V = \omega r$

The speed on the bases of the reservoir is null.

One obtains the tangential effort: $\tau = \eta \frac{V}{h}$, where h has different values for the upper and under propeller areas.

Substituting the speed, the tangential effort as a function of the variable radius r is obtained: $\tau = \eta \frac{\omega}{h} r$

The elementary surface on which the tangential effort can be considered constant is: $dS = 2\pi r dr$

The elementary friction force becomes:

$$dF_f = \tau dS = \eta \frac{\omega}{h} r 2\pi r dr = 2\pi \frac{\eta\omega}{h} r^2 dr \quad (4)$$

The dispersed power through viscous friction is:

$$dP = dF_f V = 2\pi \frac{\eta\omega}{h} r^2 dr \omega r = 2\pi \frac{\eta\omega^2}{h} r^3 dr \quad (5)$$

The total elementary power on the upper and bottom areas regarding the propeller is:

$$\begin{aligned} dP_t &= 2\pi \frac{\eta\omega^2}{h_1} r^3 dr + 2\pi \frac{\eta\omega^2}{h_2} r^3 dr = \\ &2\pi\eta\omega^2 \left(\frac{1}{h_1} + \frac{1}{h_2}\right) r^3 dr = 2\pi \frac{\eta\omega^2 (h_1 + h_2)}{h_1 h_2} r^3 dr \end{aligned} \quad (6)$$

The total power on the upper and bottom areas obtained by integrating the equation from 0 to R_1 is:

$$P_t = \int_0^{R_1} dP_t = \frac{\pi}{2} \frac{\eta\omega^2 (h_1 + h_2)}{h_1 h_2} R_1^4 \quad (7)$$

3.3 The total necessary power used to rotate the fluid

Adding the relations of the power in both areas one obtains:

$$\begin{aligned} P_c &= P + P_t = 2\pi \frac{\eta\omega^2 R_1^3 L}{R_2 - R_1} + \frac{\pi}{2} \frac{\eta\omega^2 (h_1 + h_2) R_1^4}{h_1 h_2} = \\ &= \pi\eta\omega^2 R_1^3 \left[2 \frac{L}{R_2 - R_1} + \frac{1}{2} \frac{(h_1 + h_2) R_1}{h_1 h_2} \right] = 0{,}443 \text{ W} \end{aligned} \quad (8)$$

3.4 The necessary power to rotate the propeller

The Reynolds number corresponding with the propeller rotation, using the rotating speed n expressed in rotations per second is:

$$\mathrm{Re} = \frac{nd^2}{\nu} \quad (9)$$

Considering that water is the working liquid and that the propeller diameter is d = 1 m and the rotating speed n = 2,5 rot/s, one obtains:

$$\mathrm{Re} = \frac{nd^2}{\nu} = \frac{2{,}5 \cdot 1^2}{10^{-6}} = 2{,}5 \cdot 10^6 = 2500000 \quad (10)$$

The necessary power during the operation regime is: $P = K_N \rho n^3 d^5$; using the coefficient $K_N = 0{,}93$, one obtains:

$$P = 0{,}93 \cdot 10^3 \cdot 2{,}5^3 \cdot 1^5 = 14{,}531 \cdot 10^3 W \cong 14{,}53 kW \quad (11)$$

Considering that the necessary power to start the electrical engine is 2,5 times higher than the necessary power during the operation stationary regime, it results:

$$P_p = 2{,}5 \cdot P = 2{,}5 \cdot 14{,}53 = 36{,}32 kW \quad (12)$$

For $n = 1 rot/s$, the Reynolds number becomes:

$$\mathrm{Re} = \frac{nd^2}{\nu} = \frac{1 \cdot 1^2}{10^{-6}} = 10^6 = 1000000 \quad (13)$$

With $K_N = 0{,}92$, the necessary power during the operation regime is: $P = 0{,}92 \cdot 10^3 \cdot 1^3 \cdot 1^5 = 920W$

The necessary power to start the electrical engine is:

$$P_p = 2{,}5 \cdot P = 2{,}5 \cdot 0{,}92 = 2{,}3 kW \quad (14)$$

For $n = 1{,}5 rot/s$, the Reynolds number becomes:

$$\mathrm{Re} = \frac{nd^2}{\nu} = \frac{1{,}5 \cdot 1^2}{10^{-6}} = 1{,}5 \cdot 10^6 = 1500000 \quad (15)$$

Using $K_N = 0{,}925$ the necessary power during the operation regime is:

$$P = 0{,}925 \cdot 10^3 \cdot 1{,}5^3 \cdot 1^5 = 3{,}128 W \cong 3{,}13 kW \quad (16)$$

The necessary power to start the electrical engine becomes:

$$P_p = 2{,}5 \cdot P = 2{,}5 \cdot 3{,}13 = 7{,}8 kW \quad (17)$$

It is considered convenient the function of the propeller with the rotating speed n=1 rot/s, for which the necessary power of the engine is 2,3 kW.

4. THE EFFICIENCY OF THE BIOGAS REACTOR

The filling of the reactor is 50% and the volume of biogas obtained from 1 m^3 of tank per day is 0,6 m^3 in normal conditions. The total volume of biogas obtained in our reactor during one day is 6,275 m^3. During one month the volume becomes 188,25 m^3 (Morin, 2010, Sasse, 1988).

The useful energy obtained considering the calorific power of the biogas 6,5 kWh/m^3 is:

$$E = P \cdot V = 6{,}5 \cdot 188{,}25 = 1223{,}625 kWh \quad (18)$$

The price of this energy is:

$$\mathrm{Pr}_1 = E \cdot pr = 1223{,}625 \cdot 0{,}486 = 594{,}681 lei \quad (19)$$

With the necessary power during the operation regime of 920W, the electrical energy consumed is:

$$Ec = Pc \cdot t = 920 \cdot 30 \cdot 24 = 662{,}4 kWh \quad (20)$$

The price of this energy is:

$$\mathrm{Pr}_2 = Ec \cdot pr = 662{,}4 \cdot 0{,}486 = 321{,}926 lei \quad (21)$$

The profit becomes:

$$\mathrm{Pr} = \mathrm{Pr}_1 - \mathrm{Pr}_2 = 594{,}681 - 321{,}926 = 272{,}754 lei \quad (22)$$

5. CONCLUSION

Taking into account the profit realized, we can conclude that our biogas reactor is a very useful device for the alcohol private firm to improve its efficiency. We shall try in the future to maximize the production of biogas, changing everything possible from the physical and chemical points of view. The profit can be increased considering the theoretical perspective of improving the reactor design and the mixture composition.

6. ACKNOWLEDGEMENTS

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