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INVESTIGATION ON TRANSPORT RELATED BIOGAS UTILIZATION

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Abstract. Due to an increase in demand for energy and the mobility of the human population as well as in order to keep sustainable development, there is a major need to utilize alternative energy sources. The use of biogases as a source of renewable energy could provide an effective and alternative way to fulfil a remarkable part of this demand for energy. As biogases have high inert content, their heating value is low. The energetic utilization of these low heating value renewable gaseous fuels is not fully worked out yet because their combustion characteristics significantly differ from the liquid fuels that are used nowadays in transportation, and in this way, they are not usable or their utilization is limited in devices with conventional equipment. Thus, theoretical and experimental analysis was made to investigate the usability of biogases.

Keywords: fuels, heat engines, internal combustion engines, power, natural gas, biogas, carbon-dioxide.

1. Introduction

In the last few thousand years, nature has provided a stable base of living and almost infinite supply to reserve the biosphere for humanity. In the early ages, humanity made changes in the environment with limited technology but the rate was infinitesimal compared to the size of the natural environment. Global changes were not detected. In the last two or three hundred years, there has been an explosion in the development of the industrial and technical sector that supplied people with a multiplied set of tools to encroach nature. Motorization has been developed so dynamically that the air, soil, water pollution is considerable to the amounts of those found on Earth.

Sustainable development is a kind of development where the pace of technical development, the satiation of increasing supply and the raw materials and resources of the Earth are poised so that the rate of living and the opportunities of the future generations should not decline.

Transportation cannot be replaced because it is a part of the production chain. Societies are horizontally and vertically differential. Manpower, stock and semi finished and finished products must be transported.

This paper is focusing on investigation into the combustion characteristics of biogases from the aspect of transport related utilization. The utilization of the renewable alternative energy sources like liquid bio-fuels (Bereczky 2007; Laza and Bereczky 2008) or biogases will have a major role in mitigating climate change while the increasing energy and mobility demand for humanity need to be fulfilled and sustainable development should be maintained (Török 2009; Tánczos and Török 2007; Kugelevičius *et al.* 2007; Kuprys and Kugelevičius 2009). Renewable gaseous fuels like biogases utilized in gas engines can be an alternative and effective way to fulfil a remarkable part of such demand (Meggyes and Bereczky 2007; Laza and Bereczky 2008). The transport related energetic utilization of biogases is not fully worked out yet because the combustion characteristics of biogas – due to its CO_2 content – differs from those of conventional fuels like natural gas or PB gas that have already been used in the transport sector. Therefore, theoretical investigations and measurement were made.

2. Theoretical Investigation

Nowadays, taking into account a powerful human impact considerable to the size of the atmosphere, the relation between CO_2 and the average temperature of the Earth has already been changed. Approximately a quarter of the total emission of CO_2 caused by humanity is produced by road transportation that contributes to climate change. Within the transport sector, the road transport market share is the largest and is increasing due to its superior service in terms of greater flexibility, reliability, speed and a lower probability of damage (Török 2007).

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CO_2 content has a negative effect on the combustion properties of biogases because CO_2 is an inert component and does not participate in the combustion process like the N_2 content of the air. By increasing CO_2 content, adiabatic flame temperature and flame velocity decrease (Fig. 1) which can cause burning instability and stretched combustion (Penninger *et al.* 2005). A decrease in flame temperature lowers the effective power and torque.

The value of these two parameters (adiabatic flame temperature [K], laminar flame velocity [cm/s]) is affected partly by the composition of gaseous fuel. In case of 40% CO_2 content, LHV is only around 20 MJ/m^3 (Fig. 2). From the point of view of running combustion equipment, beside LHV in case of gaseous fuels, the Wobbe number is also a very important parameter that shows the heat load of combustion equipment and can be calculated from:

$$Wo = \frac{HHV}{\sqrt{n}}, \tag{1}$$

where: *HHV* is a higher heating value [MJ/m^3] and *n* is relative density calculated from the densities of fuel ρ_{fuel} and air ρ_{air}:

$$n = \frac{\rho_{fuel}}{\rho_{air}}. \tag{2}$$

Even in case of gaseous fuels with equal HVV, the Wobbe number can vary if the composition of the fuels is different because relative density could be different. Considering that from the point of view of stable engine operation the variation of these two parameters should be kept in the range of ±5%, it is obvious that neither LHV nor the Wobbe number can be kept in the required range in case of biogas operation because typical biogas contains at least 30–40V/V% CO_2 (Fig. 2) (Kovacs *et al.* 2008).

CO_2 emission is a very important parameter from the point of view of climate change because CO_2 causes global warming, and thus it is necessary to consider the fact that the CO_2 content of biogas will appear in the atmosphere after combustion. Fig. 3 shows the maximum CO_2 proportion of the exhaust gas (CO_{2max}%) and the exhaust gas volume (V_{fg}) of different biogases calculated under stochiometric conditions.

By increasing the inert content (CO_2) of biogas, CO_2 emission (CO_2 [m^3/m^{3}fuel]) is constant, although CO_{2max}% increases while the exhaust gas amount (V_{fg}) decreases. Even though the weighted CO_2 emission of biogas is higher than the CO_2 emission of natural gas, presently, this CO_2 emission does not have to be taken into account from the point of view of global warming because it was not produced from fossil fuel and the time scale of CO_2 capture for biogas production and CO_2 emission from biogas combustion is comparable which means that there is no excess emission.

From the energetic point of view of engine operation, consumption is increasing with the CO_2 content of biogas but the effective power of the engine is decreasing as due to high inert content incomplete combustion

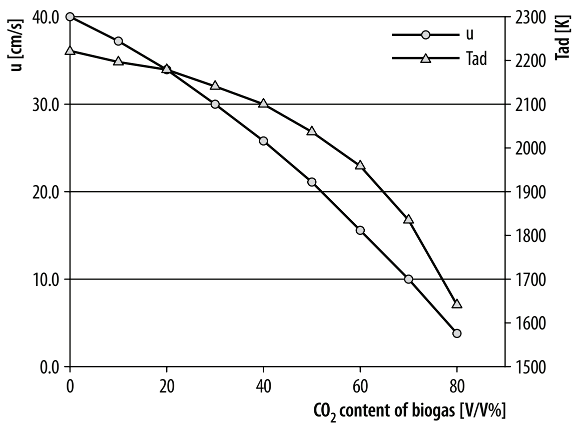

Fig. 1. Adiabatic flame temperature and the laminar flame velocity of different biogases against CO_2 content, calculated at λ = 1; 273 K; 10135 Pa (*source: own calculations*)

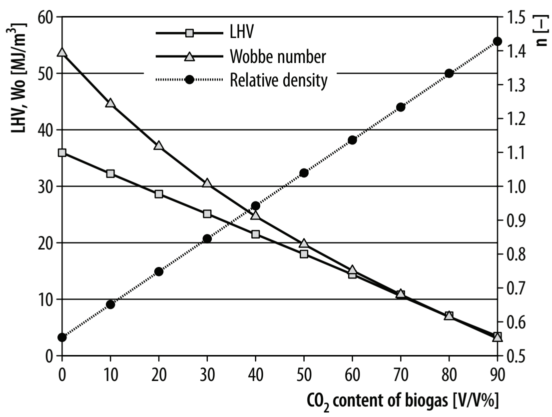

Fig. 2. LHV, the Wobbe number and the relative density values of different biogases against CO_2 content, calculated at 273 K and 10135 Pa (*source: own calculations*)

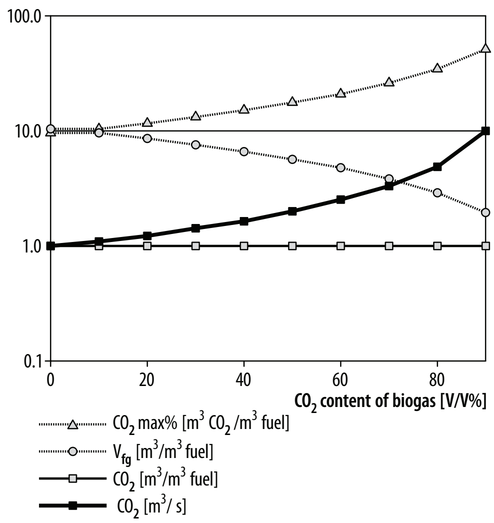

Fig. 3. The values of CO_{2max}, V_{fg} and CO_2 emission of different biogases against CO_2 (inert) content (*source: own calculations*)

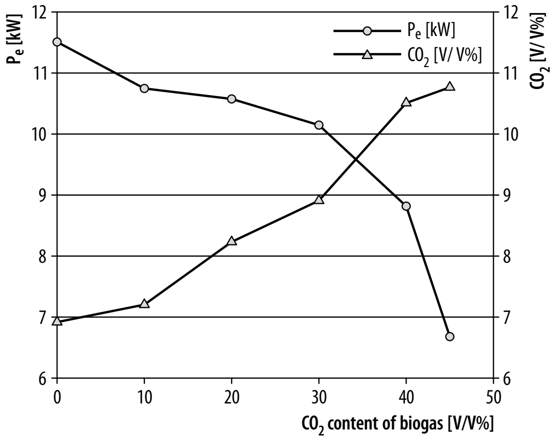

Fig. 4. CO_2 content of exhaust gas and effective power against the CO_2 content of biogas (*source: own calculations*)

takes place (Porpatham *et al.* 2008). Therefore, even with the increased consumption, the power of the engine decreases. The decrement is not really significant under 30V/V% CO_2 content but above it is intensifying (Fig. 4). Fig. 4 also shows the measured CO_2 content of exhaust gas increasing with the CO_2 content of biogas. The increment is non linear and is in good correspondence with the results of the theoretical calculations. (Henham and Makkar 1998; Huang and Crookes 1998; Uma *et al.* 2004).

3. Biogas Utilization Possibilities in Transport

Rather than ignoring the problem of increasing energy and mobility demand and following a business-as-usual approach, the international community could decide on making a concerted effort to lower its greenhouse gas emissions. While the inertia of the climate system now makes some warming inevitable, we can limit future climate change by stabilizing and then reducing emission. One aim is to calculate global CO_2 emissions from passenger car use. Carbon dioxide is produced when fossil fuels are used and burnt. The commercial intensity (i.e. fuel consumption) of the road transport sector has increased considerably during the past two decades. It is attributed generally to a larger share of traffic handled by road transport, especially by trucks hauling goods over longer distances and the rapid growth of the energy-intensive private modes of road transport.

In total, national gasoline consumption has increased from nearly 1600 million litres of gasoline in 2000 to almost 1650 million litres of gasoline in 2008 registering an increase in 50 million litres (Fig. 5). The above mentioned gasoline consumption has been consumed by motor vehicles in Hungary. According to our modelling, the amount of gasoline in 2008 with perfect burning would have caused 2 031 120 000 m^3 of CO_2 emission, would have used 2 998 320 000 m^3 of oxygen from our atmosphere (the atmosphere of Earth is: 1 083 319 780 000 km^3!) and would have produced about 50 PJ energy.

The total diesel consumption has increased from nearly 1035 million litres of diesel oil in 2000 to almost 1645 million litres of diesel oil in 2008, registering an increase in 600 million litres (Fig. 6). The above mentioned diesel oil consumption has been consumed by motor vehicles in Hungary. The relative share of diesel-powered vehicles has registered an increasing trend during the period of 2000–2008 and diesel oil consumption has been observed to increase as well due to an

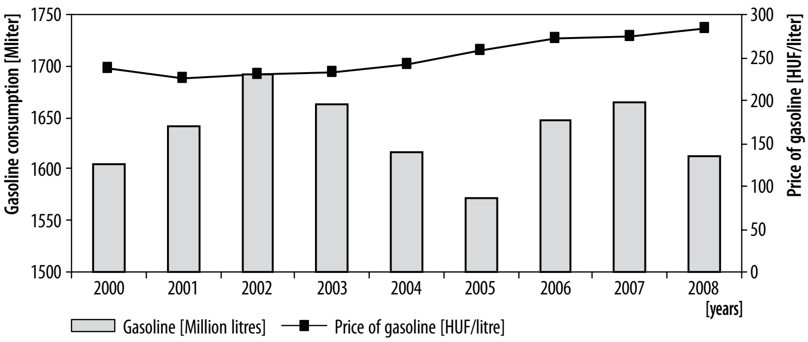

Fig. 5. Gasoline consumption and price in Hungary
(*source: Hungarian Petroleum Association, Hungarian Tax and Financial Control Administration*)

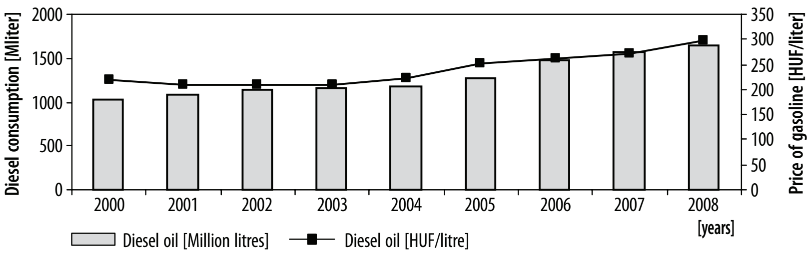

Fig. 6. Diesel oil consumption and price
(*source: Hungarian Petroleum Association, Hungarian Tax and Financial Control Administration*)

increase in freight and passenger traffic demands. All freight and passenger transport vehicles (light, medium and heavy-duty commercial vehicles) have been powered mainly by diesel engines in Hungary. According to our modelling, the amount of diesel oil in 2008 with perfect burning would have caused 2 248 715 000 m^3 of CO_2 emission, would have used 3 413 375 000 m^3 of oxygen from our atmosphere (the atmosphere of Earth is: 1 083 319 780 000 km^3!) and would have produced about 56 PJ energy.

Because of the geographical situation of Hungary, a huge volume of transit freight traffic can be observed. Biogas utilization in Hungarian freight and passenger transportation is unsolved and can only be done at international level. Beside this phenomenon, the local utilization of biogas could be possible.

4. Conclusion

Considering the theoretical investigations and measurements of biogases, it can be concluded that the transport related energetic utilization of biogases in gas engines is limited because the CO_2 content delays combustion. Above the given CO_2 content, combustion does not even take place. Accordingly, the operation range of the engine is narrowing by the increasing CO_2 content of biogas and at the given operation circumstances above 45V/V% CO_2, the engine is unable to operate by such high inert content. As consumption increases, so does the CO_2 content of the exhaust gas as well. A negative effect of CO_2 on combustion parameters is also detectable on the effective power. One of the cornerstones of transition towards more climate friendly on-road mobility schemes must therefore be to opt for technological innovations in emissions reduction, in particular, through fuel economy improvements and moving transportation away from its persistent dependence on oil to a more sustainable track through alternative propulsion systems like hybrid technologies.

Reducing greenhouse gas emission will cost money but the amounts required are clearly affordable. It is important to remember that climate policies can bring many win-win benefits. Reducing greenhouse gas emission will have to be one of the international community's top priorities over the coming decades. There will be many difficulties and detour along the road to build climate friendly economies. An alternative or complementary policy approach can be the promotion of intermodal services, mainly in freight transport. A higher market share of intermodal transport can lead to lower performance volumes in unimodal road haulage. Intermodal transport, however, still needs to be supported by different public interventions as it is not competitive enough (Bokor 2007).

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