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EFFICIENCY OF WOOD BIOMASS GASIFICATION WITH ENGINES OF INTERNAL COMBUSTION AND HEAT PUMPS APPLICATIONS

SILTUMA SŪKŅU DARBINĀŠANA AR GĀZĢENERATORA GĀZES IEKŠDEDZES DZINĒJU

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Introduction

The method of solid fuel gasification has a fairly long history since 1839 when first wood gasifier was built by Biscof in Germany. Last century in 30 and 40 wood gasification in combination with internal combustion engine was one of most popular solution for transport drives. Before World War II wood chips gasification equipment of various types was manufactured in JSC "Vairogs" in Latvia [1].

Efficiency rate of the gasifier allow to convert about 75% of fuel energy content into a combustible gas that can be used as fuel for internal combustion engine. As result of practical application of wood gasifier has been found that 1000 kg of wood combustible material could replace 365 litres of petrol during real transportation [2].

As far as wood biomass recently become significant part in fuel balance an innovative approach to it use should be considered. The purpose of this work is to evaluate efficiency of wood biomass gasification and gas use in internal combustion engine as heat pump drive.

Gasification process.

In the gasification process gases formed by burning the wood biomass with limited air supply by air draft method [2]. There are known two main types of gasifier for wood gas production when fuel are placed in fixed bed:

- the counter-current or "up draft" assume that gasification agent (steam or air) flows from bottom to upper part through fixed bed of fuel. Thermal efficiency is high as the gas exit temperature are low, but that mean presence of tar in product gas and it request extensive cleaning before use in engine or reactor.
- the co-current or "down draft gasifier" consider that agent gas flow in co-current direction with fuel (from up to bottom).The produced gas leaves the gasifier at high temperature. Since all tars must pass though a hot bed of chair, tar level are much smaller than the counter- current type.

For coal and biomass gasification are used two another types of gasifiers :

- in the fluidized bed reactor fuel is fluidised in agent gas flow as result fuel throughput is higher than in fix bed. Recycle can be used to increase conversion rate. Fluidized bed gasifier most useful for fuels contain corrosive ash.
- The entrained flow gasifier work with dry pulverized solid, an atomized liquid fuel become gasified by oxygen in co-current flow. Most coals are suitable for entrained flow because of high operating temperatures that mean tar and methane not present in product gas. The fuel particles must be much smaller than for other types of gasifiers.

Wood gasifier fuel and product gas

Wood as fuel for gasifier process could be used as chips, logs or sawdust. In the wood gasifier, the reaction at high temperature (at least 1100 C) occur between air oxygen and wood fuel in combustion area with formation of CO_2 and water vapor, then passing through the glowing layer of charcoal product gas reduced to CO and H_2 in the reduction zone. Water in fuel (wood) can be considered to be liquid form. To evaporate water to steam a significant amount of energy is consumed. About half of the weight of wood is build up from oxygen and hydrogen. Even wood could be completely dry, enough water is always released during gasification .
Wood gas contain in average of 21% of CO, 19% of H_2 and only 2% of CH_4.
The wood gas output could be 2,5 nm3 from 1 kg of dry wood material. The combustion heat of wood gas has value 5,7 MJ/kg versus 56 MJ/kg for natural gas and 44 MJ/kg for gasoline. However heat value of optimal wood gas is mixture (internal combustion engine) is about 2,5 MJ/m3 which is about 30% lower compared to air and petrol optimal mixture
(3,8 MJ/m3). During wood gas combustion in engine power loss appear because there is some suction resistance in gas cleaning chain and this results as a loss of cylinder filling.

Wood gas application efficiency

The wood gas output for electrical power production in internal combustion engine described in several works. The saw dust gasification provide efficiency of process about 43,3% but engine output was only 9,1% [3]. Another works show output of electrical power 0,5-0,7 kWh/kg of dry wood material in form of chip and log (water content in wood less than 9%)[4]. In fact the specific produced electrical power kWh/kg depending on the way of system operation (volume flow of gasification air and pressure in system).

However, if we account gasification efficiency as 75% and wood gas converting in mechanical energy in piston engine with efficiency as 25%, than total efficiency of wood combustion heat conversation to mechanical (or electrical power) could be estimated as 19%.

An energy balance applied to the system of wood conversation to power gives following equation:

$$Q_{kur} = N_{meh.zud.} + Q_{dzes} + N_{el} + Q_{silt} \quad (1),$$

where : Q_{kur} - wood combustion heat depending on wood origin equal to 3-5 *MJ/t*;

$N_{meh.zud.}$ – mechanical losses during gasification ;

Q_{dzes} - heat losses (via insulation, in gas cleaner and in gas cooler).

N_{el} - produced mechanical power in engine and

Q_{silt} - engine outlet flue gas and cooling heat energy.

Mechanical and heat losses could be estimated as 25% from Q_{kur}. , produced mechanical energy N_{el} constitute about 19% and rejected heat Q_{silt} – is about of 56 % from Q_{kur}. There are total output of (power and heat) around 75% Q_{kur} , what is close to efficiency of wood burning in boiler for heating purposes. However, wood gas allow us to get part of energy as mechanical form and our paper is devoted to implementation of this energy to increase overall heat output from wood application to heating duty.

Wood gasifier efficiency in joint operation with piston engine and heat pump

A heat pumps is a refrigeration system in which the emphasis is placed on the heat rejected in the condenser rather than the heat supplied in the evaporator. By use of mechanical power heat pump move heat from low temperature source to another place with higher temperature. For an ideal refrigeration system operating between a condenser temperature of Tc and evaporator temperature of Te the maximum coefficient of performance is derived by the Carnot cycle.

$$COP_{hp} = Tc/ (Tc-Te) \quad (2)$$

A real cycle has a lower efficiency than the Carnot cycle, because of temperature difference (delta T) between the working fluid and the source are needed to provide the heat transfer driving force.

If we consider vapour compression heat pump [5] (refrigerant R12 , delta T = 10 K, overall mechanical efficiency is ή= 86% average temperature of cold source 10^0 C and hot temperature in heating system is 35^0 C) than COP_{hp} = 5,81 and to get N_h =100 kW of heat power we had to provide following mechanical power

$$N_m = N_h /(COP_{hp}\ ή) = 20 \text{ kW} \quad (3)$$

Additionally we can warm up heating system agent (after heat pump) by piston engine

cooling system (N_{ec} = 15 kW) , engine exhaust gas energy (N_{eg} = 30 kW) and use heat from gasifier wood gas cooling (N_{gc} = 15 kW). In total we can receive following heat

power N_{th} from gasifier-piston engine-heat pump

$$N_{th} = N_h + N_{eg} + N_{ec} + N_{gc} = 160 \text{ kW} \qquad (4)$$

For mechanical power output in piston engine of N_m = 20 kW wood material consumption for gasifier could be evaluated as N_w =100 kW, when overall efficiency of wood combustion energy conversation in mechanical power is about 20%, as described above.

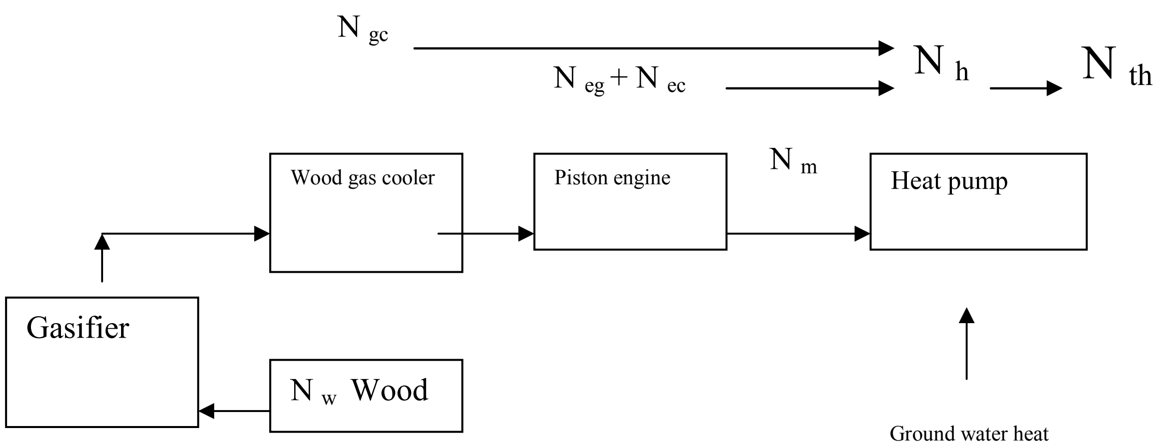

Fig. 1. Wood gasifier in operation with piston engine and heat pump energy balance.

Conclusions

The wood gasifier operation in combination with piston engine and heat pump can provide 160% heat output of 100% consumed wood material by using of low potential heat source (as ground water etc.).

There are two main advantages in comparison with electrical driven heat pump:

- high temperature flows : wood gas, exhaust gas and cooling system allow to increase heating agent temperature after heat pump, by this way we can reach even better COP and increase heat output of all system;
- the heat pump drive not produce CO_2 emission as it could be in case when electrical power are generating by oil, coal or natural burning in power generation

We consider that described system could be innovative approach for wood gasifier system with heating duties.

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Turlajs D., Rusovs D., Koksnes gazifikācijas efektivitāte iekšdedzes dzinēju un siltumsūkņu darbināšanai

Darbā veikta koksnes gazifikācijas procesu analīze iekārtās, kurās gāzģenerators tiek izmantots kombinācijā ar iekšdedzes dzinēju un siltuma sūkni. Analīze parāda, ka pašreiz šāda tipa iekārtām siltuma transformācijas koeficients ir zems (aptuveni 1,6) attiecībā pret tradicionālajām siltuma sūkņu shēmām. Vienlaikus ir iespējams uzlabot gazifikācijas iekārtu izmantošanu fosilo kurināmo un degvielas krīzes apstākļos. Zema potenciāla siltuma un aizejošo dūmgāzu siltuma kombinēta izmantošana var no jauna pievērst uzmanību koksnes gazifikācijai.

Turlajs D., Rusovs D. Efficiency of Wood Biomass Gasification with Engines of Internal Combustion and Heat Pumps Applications

Presented work contains an analysis of the wood biomass gasification unit, operating in combination with internal combustion engine and heat pumps application. Calculations shows quite low values (approximately 1,6) of heat energy transformation index against traditional heat pumps schemes. Nevertheless, there are possibilities to improve efficiency of such systems, what can become important in situation of total crysis in fossil fuels supplies and prices. Low potential earth heat and exhaust gasses heat utilization with gasgeneration could return wood gasification to a profitable system.

Турлайс Д., Русов Д. Эффективность древесной газогенерации для привода двигателя внутреннего сгоранияи теплового насоса

В работе рассмотрена схема газогенератор-двигатель внутреннего сгорания-тепловой насос. Расчёты показали, что значения коэффициента трансформации тепла такой установки низки (приблизительно 1.6) по сравнению с традиционными схемами тепловых насосов. Однако, существуют возможности улучшения схем газогенераторных установок, что может оказаться полезным в условиях кризиса поставок и цен фоссильного топлива. Показано, что совместное использование низкотемпературного тепла (земли) и тепла выхлопных газов могут сделать процесс газогенерации экономически выгодным.