Calculation of a universal energy module to provide energy and heat to the logging team

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Abstract. The article provides a comparative calculation of the heat of diesel and wood fuels released during combustion. Specific consumption of pellets for release of required amount of energy is determined and diagram of gas generator plant operating on wood fuel is presented. The plant is designed to provide heat and energy to an autonomous logging brigade.

1. Introduction
At present, due to increased competition among logging companies, the issue of improving the efficiency of such enterprises is becoming crucial.

In this regard, work is being carried out to improve the organization of work, planning and management of logging enterprises. In doing so, preferences are given to those that use environmentally friendly technologies, both in logging and for generating energy and heat through alternative fuels. Biofuels are the main source of alternative fuels. One type of biofuel is phytomass. Phytomass is the primary biomass of plant origin produced by photosynthesis. Man is known, since ancient times, for such a species of phytomass as wood. In the process of wood harvesting and processing there is a huge mass of wood waste (cutting, chips, sawdust, etc.). All this mass can and should be used as fuel for heat and electricity production. Wood waste, for the most part, is not suitable for direct combustion in combustion devices and thermal engines. They require some processing to produce working fuel. Several methods of refining waste are known: production of fuel chips, briquettes, fuel pellets, thermal processing of waste into gaseous fuel.

Pellets are pulverized wood wastes pressed at high pressure (over 30 MPa). The average dimensions of pellets are 10-50 mm in length and 5-8 mm in diameter. Pellets, compared to other refined waste, have a number of advantages:

1) low humidity, which is 8-10%;
2) low ash content of 0.9% (this advantage will reduce the overall dimensions of the gold collector in the gas generator plant);
3) high concentration of energy per unit volume (this property will reduce overall dimensions of the gas generator plant);
4) high flowability (this property will allow to automate fuel supply to the gas generator plant).

Pellets are part of the natural cycle of CO2 in the environment, are environmentally friendly fuel, as when they burn they release only as much carbon dioxide as the tree consumed when it grows. When burning pellets, the amount of carbon dioxide released into the atmosphere does not exceed the
amount of emissions that would be generated by natural decomposition of wood.

The purpose of this work is to use gas generator plant in independent mode for generation of energy and heat ensuring continuous operation of logging team.

2. Methods and Materials

As generator gas source it is proposed to use YaMZ - 236 engine transferred from diesel fuel to generator gas, initial fuel of which is pellets.

Generator gas, as a fuel, has clear advantages over direct burning of wood and other biomass types. Generator gas, like natural gas, can be passed over a long distance through pipelines and in cylinders; It is conveniently used for heating in both process and power plants. Gas combustion is easy to automate; Combustion products are less toxic than direct combustion products of wood and other biomass types. Generator gas is used as a raw material for further chemical processing and as a convenient and efficient fuel for burners of dryers, furnaces, boilers, gas turbines, but more often - gas piston plants. Thus, it is similar in properties to natural gas and can be used instead of the latter.

The theoretical foundations of wood waste gasification are devoted to many works [1, 2]. Generator gas production technology is divided into direct and reverse gasification processes.

A disadvantage of the generator gas of the direct gasification process is the high content of pyrolysis (thermal decomposition) products. Already at slight cooling and at ambient temperature, the pairs of pyrolysis products condense, killing completely the flow sections of the gas pipeline. Before transportation, especially before use in internal combustion engines, the gas requires deep purification of pyrolysis products.

Pyrolysis products are practically absent in generator gas produced in gasifier with reverse gasification process.

It is known that the gasification process first oxidizes carbon and oxygen, resulting in carbon dioxide, and then reduces the CO2 to CO carbon monoxide with absorption of heat [3]. Disadvantages of classic production of gas with direct or reverse gasification process include low combustion heat and high gas temperature at gas generator outlet, which can reach 700 - 800 °C. In order to improve the quality of the generator gas and its combustion heat, it is proposed to use the physical properties of the pellets in terms of their gasification.

In order to obtain a high calorie generator gas with low CO2 and H2O content, it is necessary to use the positive properties of pellets as follows:

1) efficient process of wood wastes gasification is possible at moisture content of gasified fuel 18-20%, which allows to supply additional heat in the form of superheated steam to the zone of gasification chamber recovery. As a result, the amount of reconstituted H2O and CO2 is increased;

2) To date, the so-called autothermal gasification process has been used, whereby the necessary heat for the endothermic reduction reaction is consumed by burning a portion of the fuel. In order to improve the quality of the generator gas, it is intended to use the heat of external sources for reducing reactions.

For this purpose it is proposed to arrange a screw gas generator on pellets in the exhaust pipe of the diesel engine YaMZ - 236.

To implement this proposal, you first need to determine the amount of heat that is consumed when the YaMZ - 236 engine operates at rated power. It is known that the engine YaMZ - 236 one of the thermal motors in which thermal energy is converted into mechanical energy on the crankshaft, which in our case should drive, for example, an electric generator station. Let us consider that in order to continuously produce the required rated power, it is necessary to supply a strictly defined amount of heat to the engine at any type of fuel. As an example, we will choose the AD-60 power plant with a capacity of 60 kW. Follows from technical characteristics of power plant that specific fuel consumption of q of the engine is 230 g / kW-h Then the nominal hourly fuel consumption will be equal to:

\[ Q_N = N \times g \left( \frac{1}{\rho_p} \right) \]  (1)
where, \( N \) is power of diesel power plant, kW; \( g \) - specific fuel consumption of diesel engine, kg/kWh; 
\( \rho_p \) - density of diesel fuel, 860 kg/m\(^3\)/l
Substitute the data in formula (1):

\[
Q_N = 60 \times 0.230 \times (1/860) = 16.1 \text{ l/h}
\]

Low combustion heat of diesel fuel \( Q_N^p = 42624 \) kJ/kg. The hourly heat flow rate will be:

\[
Q = Q_N^p \times Q_N = 42624 \times 13.8 = 588211.2 \text{ kJ/h}
\]

(2)

\( Q_N \) - nominal hourly fuel flow, 13.8 kg/h.

Pellets have relative humidity of 8-10\%. In [2, 4] it is stated that quality generator gas can be obtained from wood with moisture content of 20-22\%. Other words, pellets must be moistened before gasification. However, there is an opinion that it is better to supply the moisture necessary for the recovery reactions to the recovery zone of the gas generator in the form of highly superheated water vapor outside the gas generator, that is, with a temperature close to the temperature of the intensive course of the reduction reactions, which will affect the composition of the generator gas and its calorific value.

The elemental composition of the combustible mass is the same for all types of wood and consists of: \( C = 51.9\%; H = 6.3\%; N = 1.1\%; O = 40.7\% \).

The composition of the working mass of pellets at an average moisture content of \( W_p = 9\% \) and ash content \( A_p = 0.9\% \), after conversion according to the equation of the form:

\[
C^p = C^r \frac{100 - W^p - A^p}{100} = 46.76\%
\]

The elemental composition of the working mass of pellets is as follows: \( C^p = 46.76\%; H^p = 5.68\%; N^p = 0.99\%; W^p = 9\%; O^p = 36.67\% \).

The calorific value of the working mass of fuel pellets is determined by the empirical formula D I Mendeleev:

\[
Q_H^p = 339C^p + 1030H^p + 108.7(S^p - O^p) - 25.2W^p
\]

(3)

Substituting the composition of the working mass in the formula (3) we obtain the value of the heat released during the combustion of pellets:

\[
Q_H^p = 339 \times 46.76 + 1030 \times 5.68 - 108.7 \times 36.67 - 25.2 \times 9 = 17489.21 \text{ kJ/kg}
\]

The next stage of work was the determination of fuel pellet consumption for replacing diesel fuel on the YaMZ-236 engine. For this purpose, we determine the specific volume of pellets from the expression

\[
\rho = 1 / \rho_p = 1/640 = 0.0016 \text{ m3/kg},
\]

where, \( \rho \) is the average specific density of pellets obtained experimentally.

According to the heat consumption of the engine for diesel fuel, we determine the pellet consumption required to replace diesel fuel:

\[
g_p = \frac{Q}{Q_H^p}
\]

(4)

where, \( Q \) is the consumption of heat of diesel fuel per hour, kJ/h, \( Q_H^p \) – is the net calorific value of pellets, kJ/kg.

Substituting the values of heat in the formula (4) we obtain the necessary hourly consumption of pellets:

\[
g_p = \frac{588211.2}{17489.21} = 33.6 \text{ kg/h}
\]
From the data obtained, it can be concluded: in order to replace diesel fuel, pellet consumption of 33.6 kg / h is required.

To determine the operating time of the internal combustion engine on such a volume of pellets, we use the formula

\[ t = \frac{m}{g_p} \]  

(5)

where, \( m \) is the mass of pellets in the tank, with a volume of 1 m\(^3\), 640 kg; \( g_p \) - pellet consumption required to replace diesel fuel, kg/ h

Substituting the values of \( m \) and \( g_p \) in the formula (5) we obtain the engine operating time on the volume of 33.6 kg of pellets equal to \( t = 19 \) hours. In this case, the second pellet consumption is determined from the formula

\[ g_p^s = \frac{g_p}{3600} = \frac{33.6}{3600} = 0.009 \text{ kg/s} \]

As mentioned above, a screw gas generator is attached to the YaMZ-236 engine, a general view of which is shown in figure 1.

**Figure 1.** General view of the gas generator: 1 - screw feeder; 2 - hopper for pellets; 3 - hopper cover; 4 - tuyeres; 5 - gas generator housing; 6 - flange connection; 7 - pipe for exhaust gases; 8 - tapering body; 9 - flange connection; 10 - pipe cold air; 11 - air heater; 12 - pipe for exhaust gas; 13 - ash pan; 14 - ash pan cover; 15 - air valve; 16 - hot air pipeline; 17 - pipe exhaust chilled exhaust gases.

As can be seen from the figure, screw conveyor 1 is used to supply pellets to the gas generator. Recommendations for calculating screw conveyors are given in GOST 2037-65. The hourly consumption of pellets is 33.6 kg/h. Based on these data, it is necessary to take the performance of a screw screw 0.063 m\(^3\)/h according to GOST 2037-65.

Using this technique, we determine the diameter of the screw by the formula:

\[ D = 0.28 \left( \frac{Q}{\varphi \cdot c \cdot n \cdot y_p} \right)^{0.5} = 0.28 \left( \frac{33.6 \times 10^{-2}}{0.75 \times 0.4 \times 6 \times 0.64} \right)^{0.5} = 0.048 \text{ m} \]

where, \( Q \) is the capacity of the screw feeder, 33.6\( \times 10^{-2} \) t/h; \( \varphi \) - screw filling factor, 0.75; \( c \) - is a
coefficient taking into account the influence of the angle of inclination of the axis of the screw to the horizon on productivity, 0.4; \( n \) - is the number of revolutions of the screw feeder, 6 rpm (according to GOST 2037-65); \( \gamma_0 \) - volumetric weight of pellets, 0.64 t/m\(^3\).

According to GOST 2037-65, we accept a screw diameter of 50 mm. The screw pitch is equal to the diameter of the screw.

Determine the angle of inclination of the helix:

\[
\alpha = \arctg \frac{s}{2\pi r} = \arctg \frac{0.05}{2 \times 3.14 \times 0.025} = 17.67^\circ,
\]

where, \( s \) - screw pitch, 0.05 m; \( r \) - is the outer radius, 0.025 m

The power required for screw conveyors is determined by the formula:

\[
N = \frac{QHk}{367\eta} (W + 1) = \frac{33.6 \times 0.5 \times 1.5}{367 \times 0.85} \times (3.6 + 1) = 0.38 \text{ W}
\]

where, \( H \) - lifting height, 0.5 m; \( k \) - coefficient of friction in the bearing, 1.5; \( W \) - is the experimental coefficient of resistance when moving cargo along the gutter, 3.6.

The effectiveness of such a plant can be approximately estimated at the cost of obtaining 1 kW of energy.

The cost of obtaining 1 kW of energy from a diesel generator set is approximately 12 rubles. And the cost of getting 1 kW of energy by a gas generator unit is about 3 rubles. In addition, according to statistics, for an average logging company, a diesel generator set is unprofitable, while the effect of using a gas generator set is approximately 600 thousand rubles per year.

3. Results and Discussion

The results obtained and presented in the article confirm the effectiveness of developing a gas generator set for use in logging. Further research is aimed at the development of installations that use logging waste of a larger size and humidity than the pellets used in the work and at the development of Autonomous installations of small dimensions for the production of pellets or briquette.

References

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