The effectiveness of the small-tonnage solid composite fuel production from biomass

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Abstract. The relevance of the work is caused by necessity of the involving of local low-grade raw materials in the fuel energy balance. The purpose of the work is technical and economical evaluation to implementation possibility of the solid composite fuel production from peat as an example of the Tomsk region. The results of a processing of the low-grade raw materials at certain types from Tomsk region into the solid composite fuel are shown, their competitiveness is evaluated, the process line to production of this fuel is suggested and the economical calculation of the production organization by its basis is made. As a result, the prime cost of solid composite fuel and technical and economical parameters of investments efficiency are determined.

1. Introduction

Questions of the biomass implication (peat, wood, agricultural wastes, etc.) in the fuel energy balance are actual for several decades. At first, biomass is a renewable resource that allows is got energy fuel based on this for the long term. Secondly, the low sulfur content in biomass does not result to the formation of oxides SO_x during combustion. In addition, CO_2 emissions are not counted during combustion of biomass in accordance with the Kyoto Protocol, as amount of CO_2 which absorbed by growth of biomass under the influence of photosynthesis from the environment is equal to the amount of CO_2 which generated during its combustion [1, 2]. Thirdly, biomass is perspective raw from economic point because its reserves locate on the earth surface and do not require special conditions and huge costs for extraction.

However, low thermotechnical characteristics and local of application hinder its extensive energy use. Biomass during transportation clod, stick together and frozen in winter, because it has high moisture, thus unloading process is complicated, and biomass is made nontransportable raw.

Question of biomass implication is especially acute in remote and inaccessible areas, heat supply of which is currently provided by imported coal mainly. Long multielement distances of transportation and seasonality of delivery lead to a substantial increase in the cost of imported fuel that consequently affects to the cost of heat supply.

In view of the above, search of ways to effectively biomass implication in the fuel energy balance is an actual problem of scientific research.

2. Main provisions of the heat-technology

Replacement or upgrading of the boiler equipment park, which used in conditions of the exploitation of low power heating systems, will lead to a prolonged payback periods. According to this implication of biomass should be carried out by its processing into a solid composite fuel (briquettes, pellets, granules), which suitable for the energy use in an extensive range of the fuel combustion systems of layer type. The main part of the Russian composite fuel market is process lines of thermal biomass pressing Ruf, Pini&Kay, Nestro and etc. [3–5]. However, pressing equipment is quite expensive, and the pressing process requires high energy costs for its implementation. As a result, produced fuel has a high prime cost and, usually, can't compete with imported coal.

The authors have developed heat-technology of the small-tonnage solid composite fuel production [6–9], forming of which is based on products of low-temperature initial biomass pyrolysis. The heat technology carried out in three stages: the thermal processing of biomass, forming and drying the composite fuel. At the first stage, the biomass is exposed to low-temperature pyrolysis at a temperature 400-450 °C, resulting in charcoal (semi-coke), pyrolysis condensate (mixture of pyrolysis resin and pyrogenetic water) and gas. At stage of forming, used for this pyrolysis condensate is heated to a temperature 50-70 °C, after that in it dissolves dextrin. According to researches [6], the ratio of the pyrolysis condensate and dextrin is recommended 10:1. The resulting forming solution is mixed with a charcoal (semi-coke). The solid composite fuel is formed from mixture and draw at a temperature 20-80 °C for pellets and no more 40 °C for briquettes.

Binder based on pyrolysis condensate is forced out from stamping form when exposure to pressure: dry semi-coke without binder is remained in the form, a stable solid form and strength of which is impossible given by force of pressing up to 30 MPa. Accordingly, the production of the solid composite fuel should be ensured by forming unit of stamping type, energy consumption of which is much lower than pressing equipment.

3. Results of experimental research

The results of the processing of some type's biomass in Tomsk region to solid composite fuel as described in heat technology are shown in Table 1.

Table 1. Burning characteristics of fuels under study.

Thermotechnical characteristics	Kandinsky peat	Sukhovsky peat	Arkadjevsky peat	Woodchips
Feedstock / solid composite fuel				
Humidity W_t^r, %	72.8/0	59.6/0	38.2/0	45/0
Ash on dry basis A^d, %	9.1/19.1	39.5/40.7	31.5/51.6	0.6/2.9
Volatile yield V^{daf}, %	71.6/19.4	69.3/20.9	71.0/15.5	91.8/13.1
Lower calorific value Q_i^r, MJ/kg	3.1/21.1	4.2/14.7	7.3/13.1	9.3/29.4

The lower calorific value of fuel increases despite the increase of composite fuel ash content in comparison with the primary biomass.

Processing of biomass can be carried out without the addition of dextrin at high resin content in the pyrolysis condensate (comparable with yield of semi-coke) according to the method [10], wherein the pyrolysis resin serves as the binder. The high calorific value of the resin (for kandinsky peat – 29.4 MJ/kg, sukhovsky peat – 34.2 MJ/kg, talovsky coal – 33.1 MJ/kg) and the mineral component absence allows significantly improve the calorific value of the produced fuel. For example, the composite fuel from sukhovsky peat, which is obtained by this technology [10], has a calorific value of 17.7 MJ/kg and ash content of dry mass – 32.2 %. Woodchips can't be processed according to this method, because the pyrolysis condensate does not contain the resin.

Most of the solid fuel loss is observed during loading and unloading under transportation, as well as under fuel supply to the furnace of boiler, when it subjects to multiple falls and the subsequent destruction of entirety. As such, proving to dump according to GOST 21289-75 «Coal briquettes. Methods of the mechanical strength evaluation» is carried out as the composite solid fuel testing for mechanical strength. As a result, all test samples of the composite fuel showed 100 % of resistance to fracture, that a fully meets the requirements of GOST 54248-2010 «Peat briquettes arid pellets for heating purposes. Specifications».

The mechanical compressive strength parameters of solid composite fuel (more than 0.3 MPa) show the possibility of stack storing and warehousing with small losses.

4. Technical and economical evaluation of the implementation (as an example of the Tomsk region, Russia)

The translation of remote areas boiler-houses to local peat fuel registers in departmental plans, its will reduce the cost of energy generation and ensure energy security of settlements in the winter and the off-season, when transport accessibility misses. The total area of the Russian Federation peat fields is 80 million hectares, when concentrated is more than 186 billion tons of peat. Question by use of peat fields for Tomsk region is particularly relevant. The Tomsk region ranks second place in Russia by peat reserves. 1300 fields, constituted up 30 % of Russia peat reserves, account for region share (29 billion tons when rate of annual growth is about 1.2 million tons) [11], some of which is early drained and suited for industrial use.

The amount of the Tomsk fuel and energy market for the solid fuel boiler-houses is more than 162 thousand tons of referent fuel every year [12], but imported coal occupies 80 % of the market, and the rest share is firewood. Potentially local composite fuels, which surpass to the firewood and comparable to the imported coal by their characteristics, can cover most of the market at a comparable cost.

The Kandinsky field was chosen for cost-efficiency evaluation of thermal technological by processing peat into a solid composite fuel, in this field is currently produced mining of non-metallic materials [13–16]. The peat is stored in the field at mining without further use. If peat moisture and special aspects of thermal technology will be considered [6] then 40 thousand tons of composite fuel may be received from this field every year. However, the practice shows that the enterprise can be considered successful if its production occupies 5-10 % of the market. As such, the amount of made production was taken 45 tons of composite fuel every day at the cost-efficiency calculation. Two scripts of calculation were reviewed: optimistic and pessimistic. The way of optimistic script assumes that the initial investments are equity capital and the peat is a by-product at the mining of non-metallic materials with its cost equalled 0; at the pessimistic script – the initial investments are deposits by customers (credit for three years at 20 % per annum), the peat cost amounts 100 rub/m^3 (break-even value of peat mining for industrial use).

One example of the technic realization of heat technology is process line, layout diagram of which shows in Figure 1.

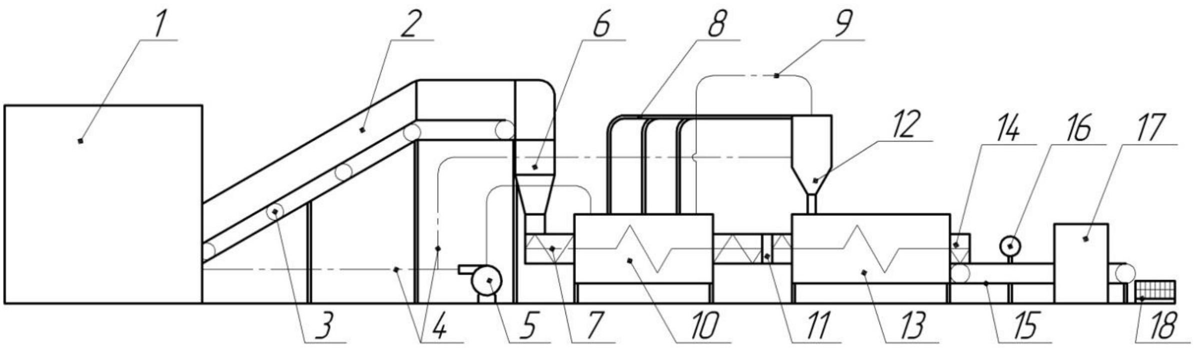

Figure 1. Layout diagram of the process line at small-tonnage solid composite fuel production: 1 – storeroom, 2 – dry of raw, 3 – conveyer, 4 – conduit of flue gases, 5 – exhauster, 6 – grinder, 7 – conveyer screw, 8 – conduit of volatile products, 9 – conduit of gas, 10 – combustion chamber, 11 – box-coupling, 12 – unit of binder preparation, 13 – heat-exchange unit, 14 – conveyer screw, 15 – conveyer, 16 – press roll, 17 – molder of stamping, 18 – dilly.

If we considered the power inputs of this process line with inputs of the composite fuel production lines from other manufacturers, which use press equipment or forming extruder, then should be noted that the specific power consumption of the equipment of this line is lower with comparing to other manufacturers.

The calculation of the production cost-efficiency for solid composite fuel (45 tons every day) was performed by the software “Project Expert 7” (Table 2). Its cost was chosen from condition that modified internal revenue rate equal 30 %. Calculation is made for 5 years.

Table 2. Parameters of investments efficiency.

Parameter	**Script of calculation**	
	Optimistic	**Pessimistic**
Cost of solid composite fuel ton, rubles	3 400	4 180
Pay back (PB), months	7	6
Average rate of return (ARR), %	72.30	73.36
Net present value (NPV), rubles	11 783 301	14 180 230
Productivity index (PI)	3.61	3.67
Modified internal revenue rate (MIRR), %	30	30

The calculations showed that composite fuel cost should be 3 400 rubles at optimistic script and 4 180 rubles at pessimistic script for the achieve of modified internal revenue rate (MIRR) value, which equal 30 %. If taking into account that cost of coal in Tomsk is 2 100-2 800 rubles/ton, then produced composite fuel at pessimistic script will be difficult to compete with it. In this case the cost of composite fuel is lowed by reducing the modified internal revenue rate (MIRR) value.

It is fair to assume that demand for composite fuel, which produced to the optimistic script and had additional advantages (ease of unloading, deficiency of dust, low moisture), will rise. In consequence of which it is possible of the production expanding, result of which is the increase of net present value (NPV).

The cost of solid composite fuel from other manufacturers, which are representing on the market now (Pini&Kay, Nestro, Ruf, pellets and other), found in range from 5 500 to 12 000 rubles per ton. The cost-efficiency of the heat-technological processing of law-grade raw materials into composite fuel according to the developed technology is obvious, if foregoing manufacturers will be regarded as the main competitors.

5. Summary

1. The new heat-technology by processing of the biomass into high calorific solid composite fuel was considered.

2. The results of the biomass processing in Tomsk region into solid composite fuel with according to this heat-technology are showed. Solid composite fuels, lower calorific value of which equal 31.9 MJ/kg, are obtained when processing of woodchips, and solid composite fuels with lower calorific value, which found in range 10.1-21.5 MJ/kg, are obtained from the least remote fields of peat.

3. Technical and economical evaluation of the heat-technological processing of peat from one Tomsk region field is conducted. The economic expediency of processing occurs when by-products or wastes of production (peat at mining of non-metallic materials, wood wastes and other) use as a feedstock.

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