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COMPOSITE SOLID FUEL: RESEARCH OF FORMATION PARAMETERS

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Abstract. Involving of local low-grade fuels resources in fuel and energy balance is actual question of research in the present. In this paper the possibility of processing low-grade fuel in the solid fuel composite was considered. The aim of the work is to define the optimal parameters for formation of the solid composite fuel. A result of researches determined that dextrin content in the binder allows to obtain solid composite fuel having the highest strength. The drying temperature for the various fuels was determined: for pellets production was 20-80 °C, for briquettes – 20-40 °C.

1 Introduction

One of the most important problems in modern energy is ensuring of energy safety countries in general and regions – particularly. Even in the Russian Federation, reached natural and fuel resources, more than 45 % of regions are dependent on the fuel delivery [1, 2]. It is also important that the fuel delivery is accompanied by transportation costs, which increased the fuel cost by several times. As a result, energy supply of such regions is provided by higher electricity tariffs and in conditions of constant depending on the integrity of traffic arteries.

The solution of this problem is involving of local organic raw materials, which often are low grade type of fuel. Such raw materials include peat, low-quality brown coal, biomass and household waste. The main problems of involving low grade raw materials to fuel and energy balance are its low thermotechnical characteristics and strength (brittleness and crumbliness). These problems lead to extraction difficult in the winter and high operational costs at traditional combustion in furnaces with grate firing: the need of raw materials drying, the high value of sifting, incomplete combustion and underburning, as a result the low boiler efficiency [3–5].

One of the most popular directions to low grade raw materials recycling for energy use is forming of fuel briquettes or pellets, called as solid composite fuel (SCF). The solid composite fuel is prepared from low grade raw materials by pressing [6] or products of its preliminary elevation, using the binder and forming equipment [7].

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The forming parameters (components rating and drying temperature) of solid composite fuel from thermal elevation products of low grade raw materials according to the technology [6] are researched in this work.

2 Material and methods

The research results for technology of fuel briquettes production from law grade raw materials, published in [8–10], and the aspiration to full using of thermal recycling products at the fuel briquettes production lead to necessary of binder addition on the stage of briquette forming.

As initial low grade fuel was researched the peat with following thermal and technical characteristics: moisture content (W_t^r) – 72.8 %, ash per dry mass (A^d) – 9.1 %, yield of volatile substances per fuel weight (V^{daf}) – 71.6 %, lowest calorific value (Q_i^r) – 3.1 MJ/kg.

The thermal recycling of peat was performed at a temperature 400 °C. The weight yield of thermal recycling products (relative the dried weight of raw materials): carbon residue – 43.4 %, pyrolysis condensate – 26.2 % (including tar – 6.3 %), gas – 30.4 %.

As it turns that a tar yield from researched peat is insufficient for based on its binder ability involving of all carbon residue to solid composite fuel. Additional of extra binder is necessary.

Dextrin was researched as one of the most accessible binders because costs for binders at production are very important factor, determined the SCF cost, and the binder process effects on their thermal and technical, strength characteristics.

Dextrin is polysaccharide, obtainable by thermal recycling potato or corn starch. It is applied mainly for adhesive means producing, as well as in food, light industry and foundry engineering.

The binder was obtained by dextrin addition to pyrolysis condensate, heated to a temperature of 50-70 °C. A binder with 5-%, 10-%, 15-%, 20-%, 30-% dextrin content (by weight) was researched. The carbon residue milled to particles of not more than 1 mm, after that mixed with binder. The ratios of carbon residue and binder was considered: (1 : 4); (1 : 3); (2 : 3); (1 : 1); (3 : 2). It is established that the binder is insufficient for forming at the using of ratios (1 : 1); (3 : 2), the mixture is too dry. The ratios (1 : 4); (1 : 3) is not allowed to form SCF due to lack of viscosity – the mixture is too liquid because a binder content is very high. The optimal ratio of carbon residue and binder in this case is (2 : 3). The water diluting is possible at low yield of pyrolysis condensate. As a result, SCF from contents in table 1 was obtained.

Using of 5% solution as a binder allows to involve all semi-coke, at the same time a homogeneous and sticky mixture was obtained. It is not resisted to forming and saved the received form. The 10- and 15% solutions using was shown the relevant or inclined to its results.

At the testing of more concentrated solutions of dextrin the forming mixture was obtained the inhomogeneous, consisting of the layers that have negative affect for SCF formation because of addition efforts to shaping.

Briquettes and pellets sizes for SCF production were chosen according by GOST 54248-2010 “Peat briquettes and pellets for heating purposes. Specifications”: pellets of 20 mm in diameter and 20 mm of height, briquettes of 50 mm in diameter and 50 mm of height.

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Table 1. Content of produced SCF.

SCF	Content
1	Carbon residue + tar (ratio 1:1) [4]
2	Carbon residue + binder (5-% dextrin content)
3	Carbon residue + binder (10-% dextrin content)
4	Carbon residue + binder (15-% dextrin content)
5	Carbon residue + binder (20-% dextrin content)
6	Carbon residue + binder (30-% dextrin content)

The drying of formed fuel (pellets) with different dextrin content was carried out at a temperature 20-40 °C. The results of mechanical compression tests for SCF according by GOST 21289-75 "Coal briquettes. Methods for the determination of mechanical strength" shows in figure 1: the highest mechanical compressive strength (P_{max}) was observed in solid composite fuel with dextrin content 5-10 %, the continued increase of dextrin share resulted to decrease of strength characteristics.

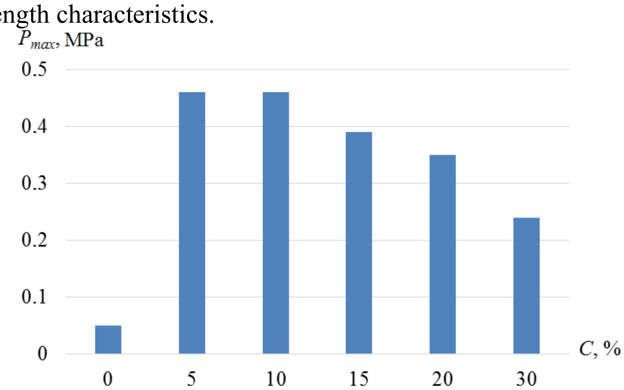

Fig. 1. The dependence of SCF (pellets) compressive strength (P_{max}) from dextrin content (C) in binder.

From practical and economical point of view [11] for SCF production is expedient to use a binder with minimal dextrin concentration, because a binder with 5 % its content has been used in further.

In example of pellets, made based on binder with 5% dextrin content in pyrolysis condensate, experimentally researched the drying temperature of SCF in the range of 20 to 140°C. The moisture losses during to drying of produced pellets shows in fig. 2a.

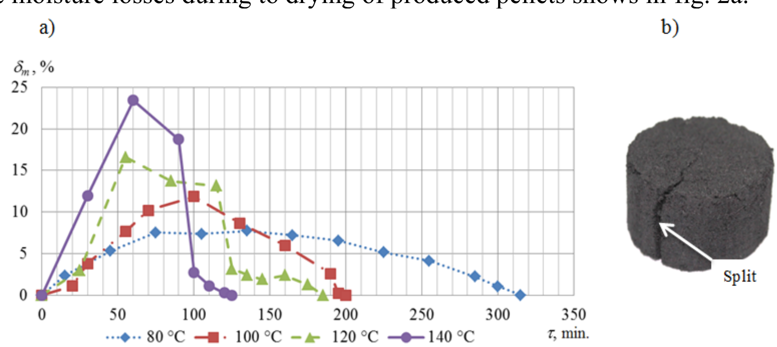

Fig. 2. The results of pellets drying: a) a moisture loss of pellet (δ_m) from time (τ) at the different dry temperature; b) pellet, dried at 140 °C.

Fig. 2a shows that moisture from SCF intensively evaporated at high drying temperature (100-140 °C). It leaded to emergence and development of surface porosity. The mechanical tests (table 2) show that all SCF examples have resistance to fracture at dropping. The results of compression test show that pellets, dried at 20-80 °C, had the highest strength. The increasing of drying temperature resulted to decrease pellets strength due to emergence pores on surface. The noticeable splits appeared at a temperature more than 120 °C (fig. 2b); it indicated to very high drying speed, sharply reduced the strength characteristics of pellet (table 2).

Table 2. The mechanical strength of the TCP depending on the drying temperature.

Type of SCF	**Drying temperature, °C**	**Characteristics of mechanical strength**	
		at dropping , %	*to compression, MPa*
Pellet	20-40	100	0.46
	80	100	0.46
	100	100	0.26
	120	100	0.26
	140	100	0.20

However, the increase of SCF size from pellets to briquettes contributed the changes to select of drying temperature. Drying of briquettes at a 80 °C lead to emergence of visible splits on their surface (fig. 3). The splits emergence explained by increase of briquettes diameter (as compared with pellets to 2.5 times), which lead to nonuniform heating.

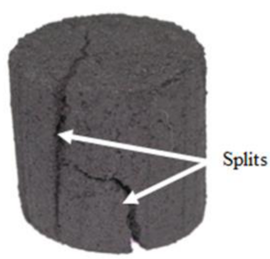

Fig. 3. Briquette (d=50 mm, h=50 mm) after drying at 80 °C.

Briquettes heated from outside surface to centre are unevenly due to low thermal conduction. A heated outside surface of briquette was solidified. In the process of continued drying the moisture inside briquette evaporated and vapor yield through an outside solidified furnace accompanied by pores formation. At the high drying speed intensity yield of evaporated moisture formed splits on surface of fuel briquette.

Briquettes with 5% dextrin content in forming mixture, dried at a temperature 20-40 °C have the following characteristics: moisture content (W_t^r) – 0 %, ash per dry mass (A^d) – 19.1 %, yield of volatile substances per fuel weight (V^{daf}) – 19.4 %, lowest calorific value (Q_i^r) – 21.1 MJ/kg, strength at dropping – 100 %.

3 Conclusions

The experiments of test dextrin in pyrolysis condensate as a binder in solution is allow to determine ratio of components for SCF forming and temperature of subsequent drying. The dextrin content 5-10 % in pyrolysis condensate at forming was ensured maximal fuel strength to compression. From practical and economical point of view is expedient to use a binder with minimal dextrin concentration (5 %). At the same time the ratio of semi-coke and binder based on dextrin was (2 : 3). The water diluting is necessary at low yield of pyrolysis condensate.

The drying temperature of SCF for pellets production was 20-80 °C, for briquettes – 20-40 °C. The higher drying temperature lead to forming of pores and splits on surface, reducing the mechanical strength of SCF. The fixed interval for pellets production is allows to producer choose the drying temperature in this range. The increased temperature up to 80 °C, allowing to reduce drying time, is preferred at high productivity. The lower temperature (20 °C) does not require of additional costs for drying, but increase the residence time of fuel at this production stage and requires the larger area for drying of SCF.

Acknowledgments

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References

1. Energy strategy of Russia for the period to 2030 (*confirm by the government edict of the Russian Federation No. 1715-p* 2009)
2. V.V. Lopatin, S.M. Martemyanov, Russ. Phys. J. **55**, 511 (2012)
3. O.S. Popel, B.F. Reutov, A.P. Antropov, Therm. Eng. **57**, 909 (2010)
4. S. A. Khaustov, A. S. Zavorin, K.V. Buvakov, N.A. Zakharushkin, MATEC Web Conf. **19**, 01020 (2014)
5. S.A. Khaustov, A.S. Zavorin, K.V. Buvakov, L.D. Kudryashova, A.V. Tshelkunova, EPJ Web Conf. **82**, 01041 (2015)
6. R. I. Muazu, Ju. A. Stegemann, Fuel Process. Technol. **133**, 137 (2015)
7. R.B. Tabakaev, A.V. Kazakov, A.S. Zavorin, Solid Fuel Chem. **49**, 267 (2015)
8. R.B. Tabakaev, A.V. Astafev, A.V. Kazakov, A.S. Zavorin, MATEC Web Conf. **23**, 01040 (2015)
9. R.B. Tabakaev, A.V. Astafev, A.V. Kazakov, A.S. Zavorin, M. Polsongkram, IOP Conf. Series: Mate. Sci. Eng. **93**, 012017 (2015)
10. R.B. Tabakaev, P.S. Gergelizhiu, A.V. Kazakov, A.S. Zavorin, IOP Conf. Series: Mate. Sci. Eng. **66**, 012052 (2014)
11. A.S. Zavorin, R.B. Tabakaev, P.Y. Novoseltsev, A.V. Astafev, MATEC Web Conf. **19**, 01015 (2014)