Composite fuel based on residue from tyre and secondary polymer pyrolysis

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Abstract. The article presents the analysis of obtaining high-quality molded solid fuel from waste that is a carbonaceous residue obtained by pyrolysis of automobile tyres and secondary polymers. Preliminary waste preparing, blending and briquetting have been carried out; fuel samples have been obtained; their strength characteristics have been studied; technical analysis has been carried out.

1. Introduction
Nowadays one of the factors contributing to the pollution of the environment is the increase in the amount of automobile tyres waste and this is a global issue all over the world. These wastes are very specific, are not susceptible to rotting and decomposing. They cover land area, polluting settlements, water basins and air. At the same time, automobile tyres waste is a valuable source of secondary raw materials and can be used to produce an alternative source of fuel.

Secondary polymers are considered to be used in the same way. Every year the production of plastics increases by 5-6%, and by 2020 the production output can reach 300 million tons. Plastics consumption in developed countries is about 100 kg per capita per year. Accordingly, the plastic waste volume increases.

The purpose of the research is to develop a technology to make composite fuel from waste of automobile tyre recycling that is a carbonaceous residue of automobile tyres and secondary polymers pyrolysis.

The research objectives are to study feed composition and to assess its adequacy for practical application; to choose a method of concentration for the carbonaceous residue; to select and study a binder; to obtain briquetted fuel and assess its quality.

The novelty of the research is the development of new alternative methods used for preparing a low-quality carbonaceous residue resulted from automobile tyres pyrolysis, which allows obtaining high-quality low-ash briquetted fuel. The development of the technology allows recycling waste into new products and has practical applicability.

There are a large number of various technologies to recycle used tyres [1-9]. The most promising method is low-temperature pyrolysis [7]. Tyres decompose at a temperature of about 450°C in the reactor. Decomposition results in intermediate products such as black oil, gas, carbonaceous residue, and metal cord. The advantage of pyrolysis is that it is environmentally-friendly. However, solid residue from the pyrolysis, that is low-quality carbon, is characterized by high ash and sulfur content, and cannot be practically applicable accumulating on the industrial site of the factory.

2. Materials and Methods
A solid carbonaceous residue obtained by pyrolysis of automobile tyres, taken from LLC "Ekoshina", Novokuznetsk, was used as an object of the research. Technical analysis of the solid carbonaceous residue obtained by pyrolysis of automobile tyres was carried out. The output of volatile substances was determined according to GOST 6382-2001 [10], while ash content according to GOST 11022-95 [11].

The obtained data are presented in Table 1. It has been identified that the carbonaceous residue has a high value of ash content and volatile substances and cannot be used without recycling.

Table 1. Results of technical analysis of solid carbonaceous residue obtained by automobile tyres pyrolysis

Test object	Analyte	Content, % wt.
Low-grade carbon	Moisture content: W^a	0.68-2.1
	Ash: A^d	10-18
	Volatile substances output: V^{daf}	8.8-12
	Sulfur content: S^d_t,	4-8

Therefore, a concentrate based on the carbonaceous residue was obtained by the method of concentration. Calorific value of the concentrate was determined in accordance with GOST 147-95 [12], sulfur content was determined according to GOST 2059-95 [13], as well as moisture content was determined according to GOST 11014-10981 [14].

The method of concentration was used as it is based on oil agglomeration. Other existing concentration methods turned to be ineffective due to the low process selectivity because of the high ash content and fine materials. The essence of oil agglomeration method consists in different wettability of solid carbonaceous particles with liquid hydrocarbons in water. As a result of turbulence in the pulp there is a selective formation of the aggregates which are thickened structurally transforming into solid spherical granules.

The solid residue obtained by automobile tyres pyrolysis was crushed to the particles of 0.1 mm size and concentrated using a pilot unit by oil agglomeration. As a result concentrates were obtained. Discharge engine oil was used as a reagent for the process of concentration.

3. Results and Discussion

At the first stage of the experiment a solid carbonaceous residue obtained by automobile tyres pyrolysis was mixed with water for 1-2 min. using a paddle stirrer connected to a motor. Then the discharge engine oil in amounts of 8.0-9.0 % wt. was added to the solid carbonaceous residue and stirred for 5-8 min. As a result, a concentrate with characteristics presented in Table 2 was obtained.

Table 2. Characteristics of the concentrate based on the solid carbonaceous residue obtained by automobile tyres pyrolysis

A^d, % wt. (ash)	4.0-5.5
W^a, % wt. (moisture content)	8.5-10.5
V^{daf}, % wt. (volatile substances output)	8.9-12.0
Q_s^r, kcal/kg (combustion heat)	6600-6700
S^d_t, % wt. (sulfur content)	0.5-1.0

Secondary polymers are suggested to be used as a binder during briquetting. In our opinion, the most suitable binder for a composite fuel from solid residue obtained by automobile tyres pyrolysis is secondary polymers wastes that are polyolefins (high-density polyethylene, low-density polyethylene, polypropylene) and polyethylene terephthalate.

Polyolefins are high-molecular compounds which are widely used in different production sectors and are easily processed. [15-17].

Polyethylene terephthalate (PET) is a complex thermoplastic polyester of terephthalic acid and ethylene glycol. Its main advantages are strength and stiffness [15-17]. Today, it is used for the production of various packaging. It is one of the most common polymers in the world, while PET recycling is underdeveloped and requires innovation.

The obtained concentrate was mixed with a secondary binder polymer (polyethylene), 8-9% by weight of the initial concentrate. After that it was put into a die mold, then placed in a muffle furnace and heated for 30 min. at a temperature of 170°C to complete melting of the binder polymer. Next, the die mold was placed under the press and the load was brought up to 100 kgf/cm² to obtain a solid briquette (Figure 1).

Figure 1. Briquetted fuel sample

Prepared samples of briquetted fuel were further tested for mechanical strength. The mechanical strength in the processes of abrasion in the drum, compression and dropping was determined in compliance with GOST 18132-72 [18] and 21289-75 [19]. Test data are shown in Table 3.

Table 3. Test results of mechanical strength of the samples

P, % (mechanical strength)	99
Compression strength, kg/cm^2	50.0
Dropping strength, % content, pieces size> 25 mm	85-99
Abrasion, % content, pieces size> 25 mm	80-90

Next, technical analysis of the samples was carried out. The results are shown in Table 4.

Table 4. Results of technical analysis of the obtained briquette

Test object	Analyte	Content,% wt.
Briquetted fuel on the basis of a solid carbonaceous residue obtained by pyrolysis of automobile tyres and secondary polymers	W^a, % wt. (moisture content)	2.5-3
	A^d (ash)	4.5-7
	V^{daf} (volatile content)	8.0-12.0
	Q_s^r, kcal/kg (combustion heat)	6800-7500
	$S^d{}_t$, % wt. (sulfur content)	0.4 -1.0

The dependence of briquette strength on the binder content was studied (Figure 2).

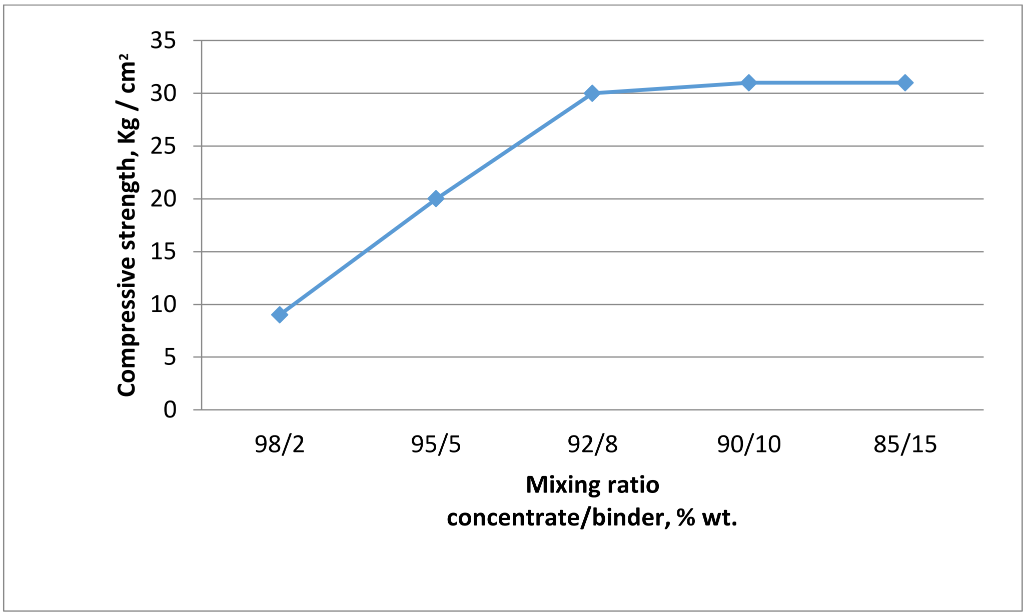

Figure 2. Dependence of briquette strength on the binder content

Briquette strength was optimal when adding a binder from 8.0 to 10.0% wt. The dependence of briquettes abrasion on the binder content is shown in Figure 3.

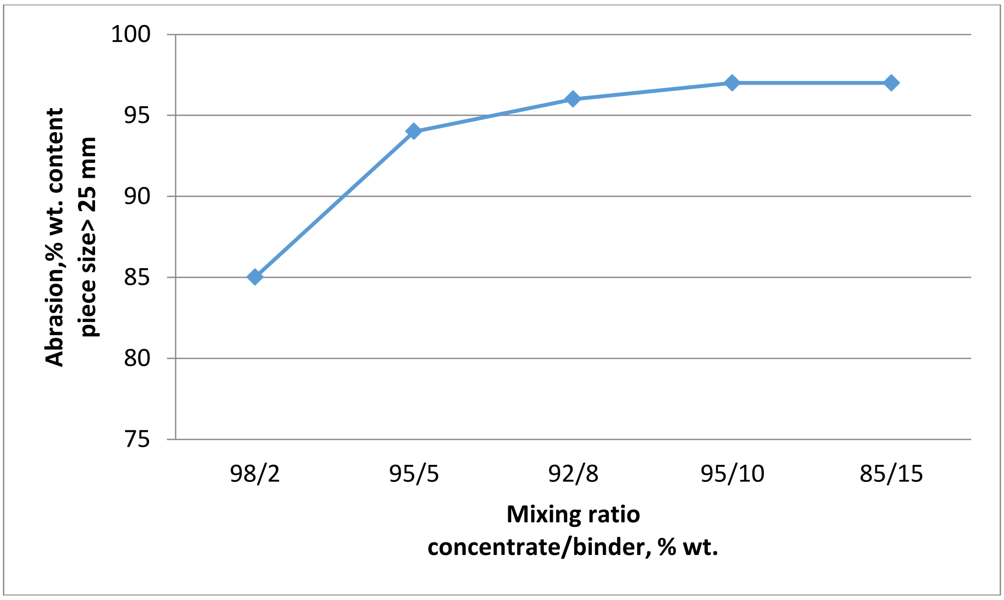

Figure 3. Dependence of briquettes abrasion on the content of binder

Briquettes abrasion strength was optimal when adding a binder from 8.0 to 10.0% wt.

4. Conclusion

The studies have shown the possibility to concentrate a low-grade solid carbonaceous residue obtained by automobile tyres pyrolysis and to get high-quality molded fuel.

Compared to its analogues, the obtained composite fuel has a number of advantages, and therefore, it is considered to be promising and competitive.

Disposal of tyres waste is suggested to be more environmentally-friendly and to expand energy resource base through the use of alternative source of fuel.

Scientific and technical research products are as follows:

1. composite fuel;
2. technology of obtaining composite fuel from solid residue by pyrolysis of automobile tyres with a secondary polymer binder;
3. high-quality carbon.

The fuel can be applied in power economy sector, for domestic boiler houses, and used by private consumers.

Thus, the research aimed at expanding application areas for carbonaceous residue obtained by automobile tyres pyrolysis is relevant. It can solve the problem of automobile tyres and secondary polymers waste disposal, which currently is one of the priorities in terms of economy and ecology, as well as an upcoming trend of business development.

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