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RESEARCH ABOUT POSSIBILITY FOR INCINERATION IN FLUIDISED BED OF WASTE MATERIALS PRODUCED BY PROCESSING OF USED LUBRICATING OILS

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Abstract. In acid refining processes of used lubricating oil with sulphuric acid it is characteristic a creation of certain amount of waste which has to be disposed in an environmentally friendly way. Waste materials produced by acid refining process are: residue after the filtration process and resinous-asphalt substance technically commonly named acid gudron. The paper presents the research results obtained in the experimental plant designed for the treatment of waste produced by refining of used lubricating oils sampled from the dump. With appropriate adjustment of process parameters, the results obtained during experimental tests in perspective would be a good basis for design of large capacity plants for treatment of waste materials such or similar physical and chemical characteristics.

Keywords: re-refining, used lubricating oils, acid gudron, sludge residue after filtration, dump.

AIMS AND BACKGROUND

Production processes in refineries generate waste materials that can be successfully used as a secondary fuel. Environmentally the most acceptable solution for the disposal of this waste material is incineration. The incineration is most often done in the industrial, energy and specially designed plants under the monitoring and quality control of flue gases[1]. The ash resulting from the combustion of waste can be used as a component in the production of cement or asphalt. Depending on

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the characteristics and type of plant where incineration takes place it is necessary to prepare the waste material which usually involves the exclusion of moisture. Extracting moisture is carried out by filtering or drying of materials. These materials are in power and industrial plants usually added as a secondary fuel to solid fossil fuel. Compared to solid fossil fuels they have a higher calorific value, and therefore in the combustion process can cause undesirable effects.

The rest of the filtration process and acid gudron are wastes that arise in the refining process of used lubricating oil with sulphuric acid. These waste materials should be disposed of in an environmentally acceptable manner. The paper presents the results obtained on a specially designed experimental plant for the treatment of waste materials generated in the process of acid refining of used lubricating oils sampled from a dump[2].

BASIC CHARACTERISTICS OF WASTE

Acid refining is one of the oldest technologies for the production of gasoline, base oil, kerosene, paraffin and used oil re-refining. This technology is rarely used today because it produces dangerous waste material which has to be disposed of in a safe way by the man living and working environment. Waste materials which are produced by using the method of acid refining are residue after the filtration process and the resinous-asphalt substance technically commonly named acid gudron. Acid gudron is a black coloured hydrophobic substance. The rest of the filtration process is a black coloured powdery substance with characteristic odour.

In acid refining processes of used oil it is preferable to do separation of raw materials according to the origin of used oil in order to provide better quality of refined oil and more economical process**.** Acid refining process with concentrated sulphuric acid generates from 3 to 10% of the waste material compared to the amount of oil which is refined. The waste material resulting from the acid refining process of used lubricating oil using sulphuric acid is classified as a category of hazardous waste and it is necessary to do its classification and characterisation in accordance with the regulations on waste management.

Waste materials produced in the refining process of used oil were deposited on unregulated dump. These materials were deposited at the dump during the period of thirty years[3]. Dump for disposal of these waste materials was closed twenty years ago. Waste materials that are found in a dump are exposed to the direct influence of atmospheric conditions. The structure of the dump in depth consists of two phases, solid and liquid (oily water). The solid phase is on the bottom and the liquid at the top of the dump. Table 1 shows the characteristic data for the waste materials created in the refining process of used lubricating oil with sulphuric acid sampled from the dump.

Table 1. Typical data for waste materials created in the refining process of used oil with sulphuric acid sampled from dump

Characteristics	Symbol	Unit	Acid gudron	Residue after filtration
Lower calorific value	*Hd*	MJ/kg	23.5	21.8
Flash point	*t*	°C	221	217
Moisture content	*W*	%	7.25	6.12
Annealing loss at 550°C	-	%	43.75–38.69	36.22
Ash content at 550°C	*A*	%	56.25–61.31	63.78
Content of elements (AAS)				
Sulphur	S	%	2.6–3.4	0.27
Zinc	Zn	mg/kg	5.7–304	2.82
Tin	Sn		16	1.1
Cobalt	Co		0.7	2.2
Iron	Fe		21–450	8.94
Lead	Pb		4.5–569	8.0
Magnesium	Mg		6.1–71	17.43
Copper	Cu		0.8–207	4.2
Chromium	Cr		0.5–6.6	5.2
Calcium	Ca		36.5–792	11.17
Sodium	Na		7.1–24.3	19.8
Potassium	K		40.1–149.5	80.5
Silicon	Si		7.6	0.0
Mercury	Hg		less than 0.02	0.0
Polychlorinated biphenyl	PCB		0.1–0.3	0.01

The acid gudron is extremely undesirable waste material and is not allowed its disposal into the environment. However, there are several procedures today for its disposal. In Germany acid gudron is used for obtaining of sulphuric acid and oleum, as well as for the obtaining of raw materials used in the cement industry.

The most commonly used technologies for treatment of gudron waste are[1]: solidification/stabilisation, disposal, incineration in power plants, incineration in cement plants, pyrolysis, plasma treatment, controlled incineration, thermal desorption and others[4,5].

Ecologically the most acceptable method for disposal of acid gudron and residue after filtration generated in treatment of used lubricating oil with sulphuric acid is controlled incineration. Most often these waste materials are incinerated in[6]: bulk form, briquette form and fluidised bed[7,8].

During incineration in bulk form oily waste material is mixed in an appropriate ratio with a suitable cellulosic material, which maintains the mixture in bulk form. This mixture proved to be an extremely useful addition to the low calorie coals incinerated in power plants.

In incineration process of oily waste which is in briquette form, the preparation and mixing is carried out as in the previous case, by adding the required binder material. From the mixture prepared in this way briquettes of suitable size are produced. In this form the mixture is suitable for burning in a suitable furnaces[6,9].

Incineration in a fluidised bed usually is used for oily waste materials with increased presence of sulphur (waste material generated in used lubricating oils re-refining process). The process is carried out in a furnace having a fluidised bed of inert material. In order to facilitate the process in the furnace silicon dioxide (SiO_2) is usually used as the inert material. Incineration in a fluidised bed is one of the most acceptable procedures for the incineration of refinery waste. In this process, temperature of incineration is ranging from 800 to 950°C. The emission of waste gases from the combustion chamber during combustion in a fluidised bed is affected by the following process parameters: the ratio of sorbent material to sulphur emitted from fuel during combustion, height of fluidised bed, fluidisation velocity, particle size and type of sorbent material, the temperature and pressure in a fluidised bed. Depending on the regime of fluidisation, i.e. speed flow of gas through the fluidised bed there are stationary or bubbly fluidised bed (particles of the bed are moving intensely and chaotic, but the fluidised bed is stagnant as a whole) and circulating fluidised bed (inert material of the bed is in the fast fluidisation regime and moves through the entire combustion chamber vertically upwards, then separated from the stream of products of combustion back to the bottom of the firebox), i.e. boilers with bubbling and circulating fluidised bed that can operate in conditions of atmospheric pressure or at elevated pressure.

EXPERIMENTAL INSTALLATION AND DESCRIPTION OF TEST

At the experimental installation tests were made in order to determine the parameters of the combustion of waste material, which is a mixture of acid gudron and wastes generated by filtration in the refining process of used lubricating oils. Also, the goal of this research was to determine the efficiency of flue gas desulphurisation by dry method by adding limestone.

Acid gudron and waste generated by filtration in the refining process of used lubricating oils are divided into two lagoons in the landfill. Sampling of waste materials was done directly from the lagoons and after that the preparation for the test was carried out. Preparation for the test included filtration and drying of waste material to the appropriate humidity.

The experimental plant is a firebox with vertical structure whose internal diameter is 200 mm. At the height of 1 m from the bottom, the diameter of firebox is increased to 280 mm in order to reduce flow velocity of the material which should be fluidised, and the reduction of removal of solid particles from the bed of inert material. The total height of the experimental plant is 4 m. Experimental plant is isolated by chamotte over the entire height, in order to eliminate the influence of ambient temperature.

The plant is equipped by height with connectors for temperature, pressure and sampling of flue gases and solid particles in the fluidised bed area at each 150 mm and above that at each 500 mm by height.

For combustion is used compressed air, whose distribution into the firebox is done by using a nozzle with a diameter of 60 mm which circumferentially has five evenly spaced holes with a diameter of 14 mm. The system of air supply is equipped with necessary fittings and measuring devices for measurement and control of pressure and quantity of air for combustion.

Supply of waste material into the firebox provides screw feeder with adjustable slope of the worm coil. Drive is done through the belt, using 3 kW electric motor.

For the process of fluidisation is used inert materials, silicon – dioxide (SiO_2) granulation of up to 1.5 mm.

The flue gases produced in firebox are leaving in two parallel-connected cyclones and then in the environment. Separated flying particles in the cyclone are sampled for analysis and further processing.

In order to keep the sulphur compounds from flue gases in firebox limestone is directly added into the fluidised bed. Limestone is added to form calcium oxide, which reacts with SO_3 from flue gases.

Figure 1 shows the technological scheme of the experimental installation for monitoring the parameters of combustion of the waste material that is a mixture of acid gudron and wastes generated by filtration in the refining process of used lubricating oils.

In order to start the experimental plant, the system of air supply is equipped with 10 kW electric heaters, for heating the air for fluidisation which allows heating the layer of inert material to a temperature of 400^{o}C for about 35 min.

Prior to experimental tests, the neutralisation of acid gudron is carried out using $Ca(OH)_2$. That is followed by the mixing of neutralised acid gudron with waste produced during filtration in relation 1:1. Thus prepared material is ready for testing at the experimental installation. This ratio in the mix has been adopted because there are usually on the landfill approximately equal amounts of both waste materials. Table 2 shows the elemental composition of material for experimental testing which is a mixture of neutralised gudron and wastes produced by filtration in the refining process of used lubricating oil.

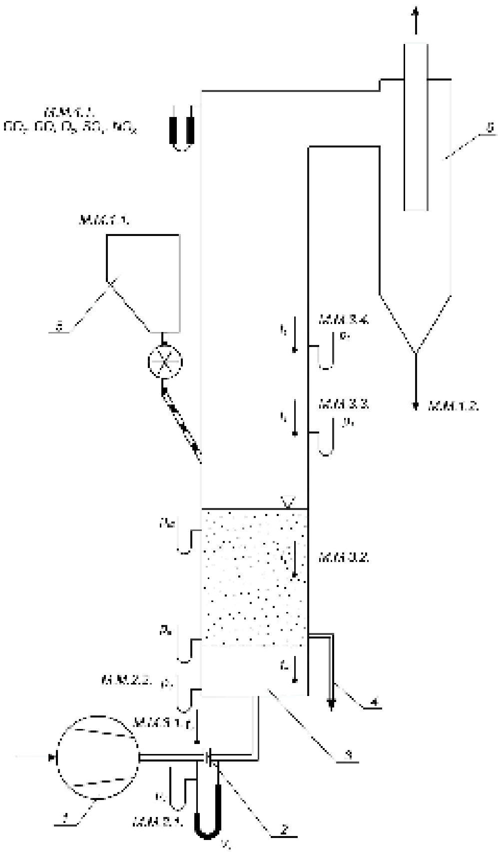

Fig. 1. Technological scheme of experimental installation: *1* – fan, *2* – measuring reactor, *3* – firebox, *4* – drainage pipe, *5* – dispenser, *6* – cyclone

Table 2. Elemental composition of the material prepared for testing

Elemental composition	Carbon (C)	Hydrogen (H_2)	Sulphur (S)	Nitrogen (N)	Oxygen (O)	Ash (A)	Moisture (W)
Value (%)	25.93	4.73	1.60	0.77	2.81	58.60	5.56

Dosage of the material prepared for the testing begins at a temperature of layer of inert material from 400°C and the established fire in the furnace with the aid of coal. Once the fire is established in the firebox and the required temperature of the inert material, coal is no longer used, but it is dosed tested material. The temperature rise of an inert layer of 400°C to steady state test was realised by dosage of tested material.

Table 3. Results of experimental tests

Measuring point	Characteristic	Symbol	Unit	Result
M.M. 1.1.	quantity of tested material	G_u	kg/h	9.7
	lower calorific value of tested material	*Hd*	MJ/kg	14.206
	bulk density of tested material	ρ_g	kg/m^3	1250
M.M. 1.2.	quantity of ashes separated in the cyclone	G_1	kg/h	4.2
	unburned in fly ash	C_n	% mass.	2.1
M.M. 2.1.	air pressure at the plant entrance	p_v	bar	5.5
M.M. 2.2.	air pressure in the installation	p_d	mmH_2O	305.4
	excess air coefficient	λ_d	–	1.28
M.M. 3.1.	air temperature at the plant entrance	t_v	°C	17.0
M.M. 3.2.	temperature of inert material bed (190 mm from the bottom)	t_s	°C	717.3
M.M. 3.3.	temperature of inert material bed (390 mm from the bottom)	t_1	°C	922.7
M.M. 3.4.	firebox temperature (1000 mm from the bottom)	t_2	°C	716.2
M.M. 4.1.	composition of the flue gases at the top of the firebox			
		CO_2	%	11.3
		CO	%	trag
		O_2	%	3.2
		SO_x	ppm	418.0
		NO_x	ppm	23.0
	Fluidisation velocity	v_f	m/s	1.21
	Degree of desulphurisation of flue gases	E_{dg}	%	82.02

During the experimental testing, there were more working regimes with mutually approximate value of the measured values. Table 3 shows the results obtained in one of those regimes.

Visual monitoring of the process during the experimental test has confirmed the existence of intensive mixing in a fluidised bed and a good flame compliance by volume of firebox under all operating regimes, which indicates the optimum kinetics of thermal decomposition process of the tested waste materials.

From the relationship between temperature of the layer and the temperature above the layer can be concluded that the combustion process of the tested material is moved into the heating space above the layer.

Based on the obtained measurements can be noticed that complete combustion is achieved with negligible content of carbon monoxide (CO), where the excess air coefficient was around 1.3.

Based on the the results obtained by measuring the efficiency of flue gas desulphurisation by adding $Ca(OH)_2$ it can be seen that the overall degree of desulphurisation is 82%, which is quite satisfactory. SO_x content in the exhaust flue gases is above the prescribed by law values and it should try to apply the wet processing of output flue gases.

During the experimental tests it was measured quite high concentrations of flying solid particles in flue gases at the outlet of firebox, although the fluidisation velocity was approximately about 1.2 m/s. This is understandable, bearing in mind that in the firebox enered a relatively large amount of $CaSO_4$ by neutralised gudron and a large amount of clay powder by waste material from the filtration process.

CONCLUSIONS

Results obtained during experimental tests show that the waste materials produced in re-refining process of used lubricating oil can be successfully incinerated in the firebox with fluidised bed in properly defined parameters of the combustion process.

Performed experimental tests have shown that the content of polluting components in flue gases at the outlet of firebox from an environmental point is acceptable, except of sulphur oxides that must be subsequently eliminated by appropriate treatment.

The conducted tests and obtained in perspective could be used in designing of the plant with greater capacity for the treatment of waste material, that has been produced in the refining processes of used lubricating oils. However, it would be useful to perform tests on the experimental installation at mutually different ratios of neutralised gudron and waste produced in filtration process and after obtaining of these results, design the plant with greater capacity.

REFERENCES

1. N. GOKCE.: Evaluating the Waste Issue and Its Environmental Effects in Turkey. Oxid Commun, **39** (1), 776 (2016).
2. J. PRASITYOUSIL, A. MUENJINA: Properties of Solid Fuel Briquettes Produced from Rejected Material of Municipal Waste Composting. Procedia Environmental Sciences, **17**, 603 (2013).
3. D. KRCMAR, S. BALOS, B. DALMACIJA, M. PRICA, J. TRICKOVIC, S. RONCEVIC, S. MALETIC: Mechanical Properties of Thermally Stabilized Sediment-Clay Mixtures. J Prod Eng, **17** (1), 97 (2014).
4. S. SIMIC, B. DESPOTOVIC, M. STANOJEVIC, Z. PETROVIC: Explore the Possibilities of Use for Energy Purposes of Waste Material from the Processing of Base Oils Active Clay. In: Proc. of the 27th International Congress on Process Industry 'Process Engineering' SMEITS Belgrade, Belgrade, 22–24.09.2014.
5. S. SIMIC, D. GOLUBOVIC, B. SAVKOVIC, P. KOVAC, D. JESIC: Monitoring of Wood Briquettes Combustion Parameters Depending on Share Waste Materials Obtained from Refining Process of Base Oils and Paraffin. Oxid Commun, **39** (4-II), 3291 (2016)
6. S. SIMIC: The Waste Refinery Supplies Fuel Quality, Law and Environment in the Economy And Practices. EKO-JUSTUS I, Kopaonik, 09–12.06.2008, 89–92.
7. LI YU, YIHUI CHEN, FANG HE: Supercritical Water Oxidation of Waste Drilling Fluid. Oxid Commun, **39** (2), 1694 (2016).

8. CHAO WANG, PENGCHENG LIU, JIAQI LIU, WENHUI LI, XIAOKUN ZHANG: Oxidation of Waste Drilling Fluid with KOH Addition in Supercritical Water. Oxid Commun, **39** (2), 1700 (2016).
9. G. LAZAROIU, I. OPREA, L. MIHAESCU, T. PRISECARU, I. PISA, G. NEGREANU, C. R. MOCANU: Biomass Briquettes from Pit Coal-Wood: Boiler Test Facility Combustion Case Study. J Environ Prot Ecol, **13** (2), 1070 (2012).

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