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APPLICATION OF FLUIDIZED BED COMBUSTION TECHNOLOGY FOR UTILIZATION OF POST-ROLLING OILY WASTES

SŁAWOMIR LESZCZYŃSKI

University of Science and Technology, Department of Heat Engineering and Environmental Protection
al. A. Mickiewicza 30, 30-059 Kraków, Poland

COMMUNICATION

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ZASTOSOWANIE TECHNOLOGII FLUIDALNEGO SPALANIA DO UTYLIZACJI POWALCOWNICZYCH ODPADÓW OLEJOWYCH

W pracy zaprezentowano badania z zakresu zastosowania technologii fluidalnego spalania do utylizacji powalcowniczych odpadów olejowych na złożach zeolitowych. Powalcownicze odpady olejowe zaliczane są do jednych z najbardziej uciążliwych odpadów pochodzących z przemysłu metalurgicznego z uwagi na zawartość wielu substancji toksycznych. W niniejszej pracy badania laboratoryjne zostały przeprowadzone na małym, eksperymentalnym w pełni oprzyrządowanym piecu do fluidalnego spalania. Wyposażenie pomiarowe stanowiska i komory spalania umożliwiało pomiar podstawowych parametrów procesu spalania wraz z analizą składu gazów spalinowych. W efekcie umożliwiło to prowadzenie procesu spalania przedmiotowych odpadów jak najefektywniej z jednoczesnym uwzględnieniem minimalizacji obciążenia środowiska naturalnego emisją składników toksycznych.

Summary

The article presents the investigations of fluidized combustion of oily wastes derived from cold rolling-mill process on a zeolite bed. Oily wastes generated in the rolling-mill process are one of the most hazardous residues from metallurgical works because the toxic additives content. The experiments were carried out using a small laboratory combustor with full measurement equipment. The measurement apparatus associated with the combustion chamber made it possible to measure the basic parameters of the process including the composition of exhaust gasses. It has been shown that the combustion of oily wastes from cold rolling-mill process can be conducted efficiently and friendly for the environment.

INTRODUCTION

The iron and steel metallurgy is, in addition to the mining and power industries, one of the principle branches of Polish raw materials industries. The Polish iron and steel industry systematically modernized is however a huge source of hazardous pollutants which are dangerous for the environment.

Oily wastes derived from metallurgical process are one of them [5]. The considerable amount of this kind of oily waste is generated in the cold rolling-mill processes. These oily wastes originating from the cold rolling-mill of steel plates are easily identified by various reasons of chemical and physical properties and place of generation.

The quantity and the composition of this stuff make the application of the fluidized bed combustion possible for its utilization. This method lets recover energy from oily wastes and it assures rapidity and effectivity of the process.

CHARACTERISTICS OF POST-ROLLING OILY WASTES

Various kinds of emulsions and oils are used as antifriction agents during the cold rolling process. Waste emulsions are very harmful materials because of the content of toxic additives. Emulgators, detergents, corrosion inhibitors, and antifoaming agents are substances, which occur in the rolling mill emulsions. Annually almost 2,000 Mg of oily wastes is produced by rolling industry.

The oily wastes after the first step of purification and the second stage of dewatering in filters, a moisture content in the wastes is in the range of 60 to 80%, and additional processes may decrease a moisture up to 30–60%. However, the final composition of oily mixture separated during filtration depends on the primary composition of the rolling-mill emulsion.

Oils including lubricating oil, engine oil and hydraulic oil are used most often as the lubricants during the rolling-mill process (Table 1). The component analysis of hydrocarbons is presented in Table 2.

Table 1. Percentage composition of the rolling-mill oily mixture

Kind of oil	[%]
Lubricating oil	60–75
Engine oil	10–25
Hydraulic oil	5–15
Turbine oil	1–3

Table 2. Component analysis of hydrocarbons in the rolling-mill emulsion

Kind of hydrocarbons	[%]
Paraffinic-naphthnes hydrocarbons	55–72
Aromatic hydrocarbons	25–36
Resins	2–3

The additional physicochemical and thermal properties for three groups of oily wastes are presented in Table 3. The samples were collected from different points of the purification system:
- this sample was collected from the surface of wastes tank after filtration and later was dewatered by gravitational settling and vaporization,
- this sample was collected from the bottom of wastes tank after filtration and later was dewatered by gravitational settling and vaporization,
- plant fats.

Table 3. Analysis of rolling-mill oily wastes

Denotation	Sample		
	1	2	3
Moisture [%]	7.65	5.63	14.24
Solid matter after ashing [%]	10.55	50.66	10.06
Carbon [%]	61.65	31.78	60.15
Total hydrogen [%]	9.70	5.02	9.26
Hydrogen in the analytical sample [%]	9.01	4.54	7.76
Combustible sulphur [%]	0.12	0.16	0.25
Total	88.98	92.77	92.46
Oxygen + nitrogen [%]	11.02	7.23	7.54
HHV [kJ/kg]	32616	16525	30 893
LHV [kJ/kg]	30487	15142	28 802

FLUIDIZED COMBUSTION TECHNOLOGY OF OILY WASTES

The fluidized bed combustion technology can utilize different kinds of low quality and low calorific value fuels many a time impure. A large majority of these fuels can not even be burnt using conventional methods. The usefulness and economical advantages of fluidized combustion technology for utilization of solid fuels have been confirmed in many industrial conditions [3, 4]. Whereas, the fluidized beds can also be used to burn liquid industrial wastes, but up till now the method has not been widely used for wastes derived from metallurgical works.

In this case, the application of the fluidized combustion on zeolite bed makes it possible to reduce:
- the preliminary preparation of oily wastes to the gravitational methods only,
- SO_2, NO_x and other refraction pollution during the fluidized bed combustion process [2].

CHARACTERISTICS OF ZEOLITE SORBENTS

Natural zeolites (clinoptilolite and mordenite) own selective adsorption properties capable of separating components of a raw gas, pyrolitical gas and exhaust gas mixture in molecular size (cages and channels) and on the surface [1]. Zeolites are crystalline aluminosilicates with fully cross-linked open framework structures made up of corner-sharing SiO_4 and AlO_4 tetrahedra [6]. Table 4 summarizes their mineralogical, chemical and physical parameters.

Table 4. Characteristic data of zeolites

Data name	Clinoptilolite	Mordenite
Mineralogical composition [%]		
Clinoptilolite	45–60	–
Mordenite	0–3	50–70
Quartz	10–15	15–20
Montmorillonite	6–8	5–7
Silt	4–7	3–5
Glass of volcano	8–10	15–20
Ash	2–4	3–4
Chemical constitution [%]		
SiO_2	68–74	73–76
Al_2O_3	10–13	10–12
Others	11.98–20.43	10.18–19.93
Physical properties		
Density [g/cm^3]	2.4	1.8–2.0
Bulk density [g/cm^3]	0.9	0.8–0.85
Surface area [m^2/g]	10–15	50–100
Porosity	0.34	0.25– 0.3
Pore sizes [nm]	0.79–0.35	0.57–0.29
Hardness [Mosh]	3–4	3–4

EXPERIMENTAL AND RESULTS

The experimental arrangement used for the fluidized bed combustion is schematically presented in Fig. 1.

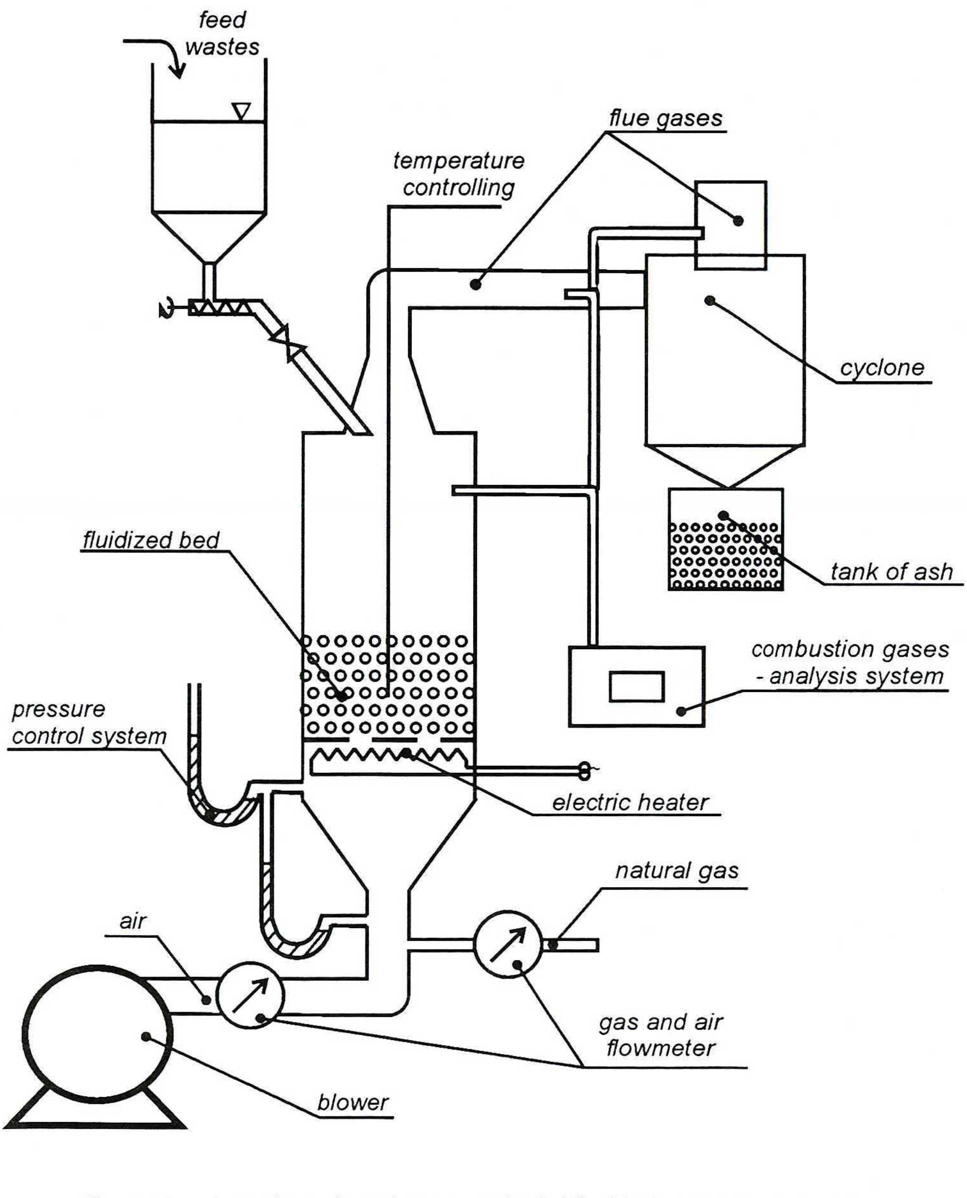

Fig. 1. Flow sheet of experimental apparatus for fluidized bed combustion technology

The system consists of a blower, an air preheater, a fluid bed reactor, cyclone for dust removal and tank for its accumulation. The combustor is 130 mm in diameter and 800 mm high. The fluidized bed combustor was externally heated by use of electric furnace and natural gas. The temperature of the bed was controlled by K-type thermocouple. The gas flow was monitored by calibrated rotameter and pressure drops were measured by mercury or water manometers.

The combustion air from a blower passes through a preheater with natural gas and heats the bottom at the bed. The bed temperature is maintained at around 950°C (temperature distribution in a fluidized bed is shown in Fig. 2). The combustion gases leaving the bed enter an expanded freeboard area. The gas velocity is reduced causing the larger entrained particles into fixed and fluidized bed.

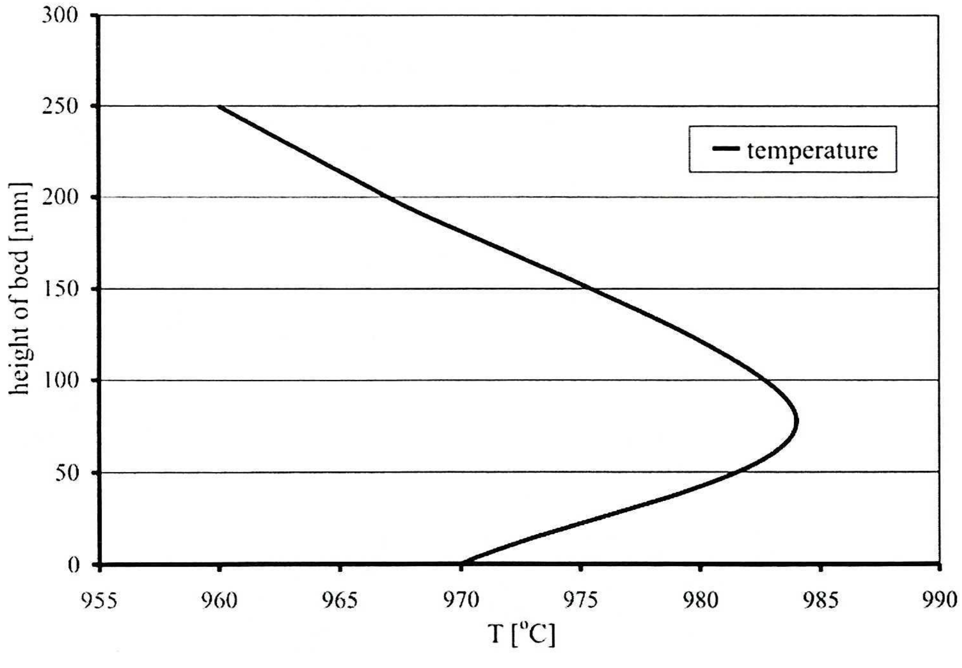

Fig. 2. Distribution of temperatures in the fluidized bed

The experiments were always made on two-layer bed with an initially segregated material of bed. The bottom layer of the bed was stationary (inert particles of electrical filter-dust) whereas the top layer of the bed was fluidized (clinoptilolite, mordenite). The stationary layer of the bed was used in combustion process as a fire grate for steady distributing of fuel-air mixture in combustion chamber and for maintenance of small zeolite sorbent.

For the majority of experiments the zeolite bed contained equal volumes of two components (clinoptilolite, mordenite) although in a few experiments 40% and 60% zeolite mixtures were used.

Characteristic diameters for the beads of electrical filter-dust were $d_{50} = 10$ mm and $d_{90} = 15$ mm, for clinoptilolite $d_{90} = 5$ mm and for mordenite $d_{90} = 1$ mm. Fig. 3 shows the results of a fractional analysis for clinoptilolite and Fig. 4 shows a similar analysis for mordenite.

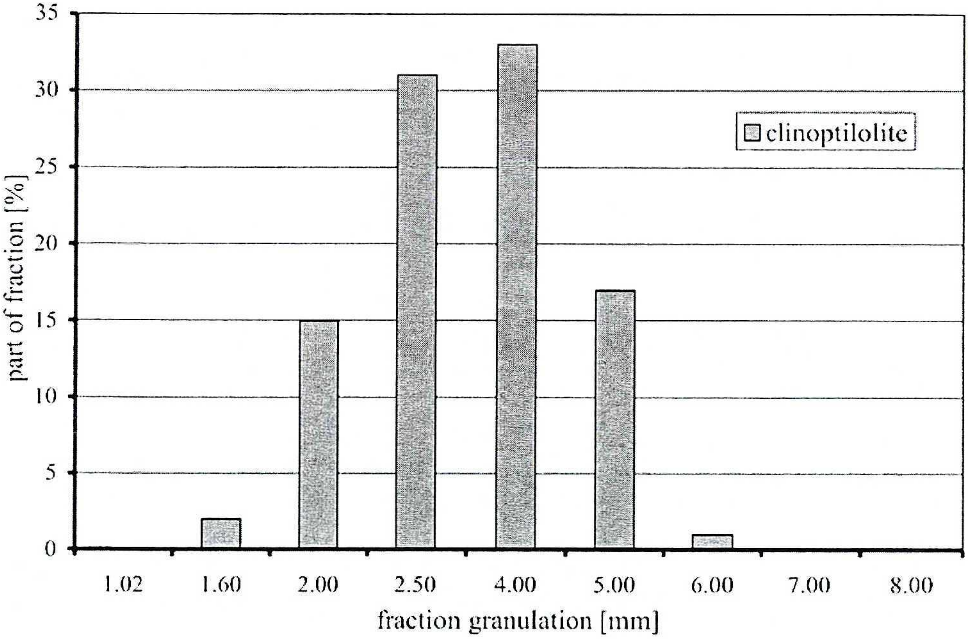

Fig. 3. Fractional analysis for clinoptilolite

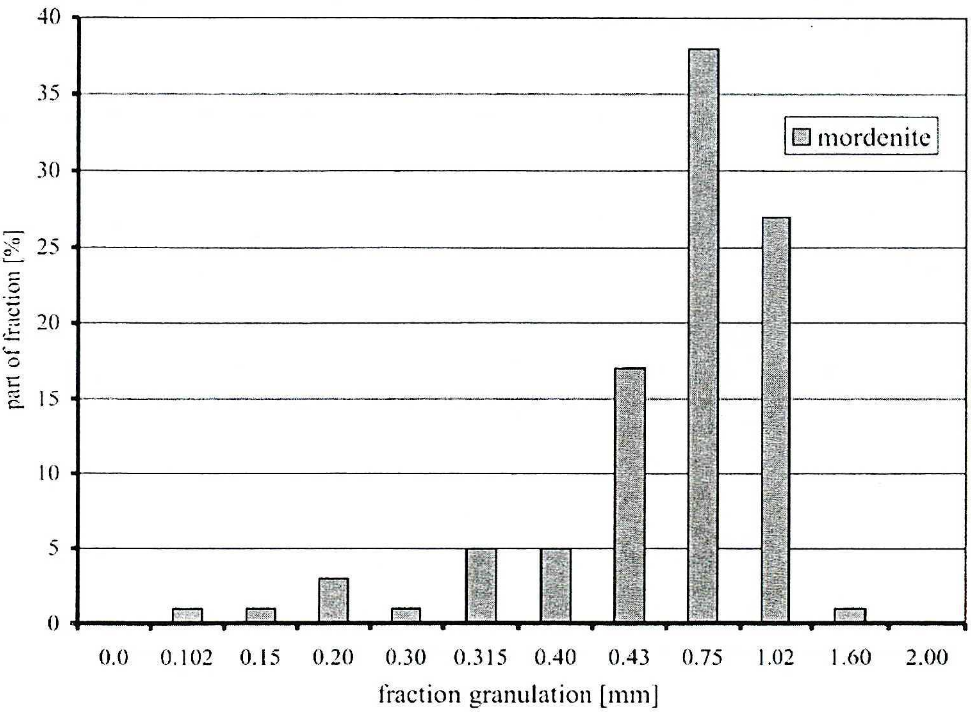

Fig. 4. Fractional analysis for mordenite

The static bed height was chosen to be 100 mm. Initially, before each experiment the solid particles of electrical filter-dust were burnt. During the burnt-out process natural gas was used as an energy carrier. Table 5 shows the characteristic parameters of the flue gas analysis.

Table 5. Data of flue gases after the burn-out cycle

Denotation	O_2, %	CO_2, %	CO, ppm	NO_x, ppm	SO_2, ppm	Temperature of bed,°C
Concentration	11.5	7.1	1001.6	71.4	73.1	950

The full bed height used was 250 mm and the experiments were conducted by carefully placing the two layers of solids in the reactor and adjusting the gas rate to the desired value. For this work fluidized velocity range was changed from 1.2 to 2.5 m/s and excess air λ from 1.5 to 1.7.

The reduction results for toxic component concentration of CO, NO, SO_2 in fluidized combustion, by comparison without zeolite and on the zeolite beds for samples: 1, 2, and 3 post-rolling oily wastes are presented below in Figs 5–7.

The final concentration of oxygen in flue gases at the level below 11% made it possible to obtain the maximal bed temperature of 950°C after switching off natural gas as auxiliary fuel.

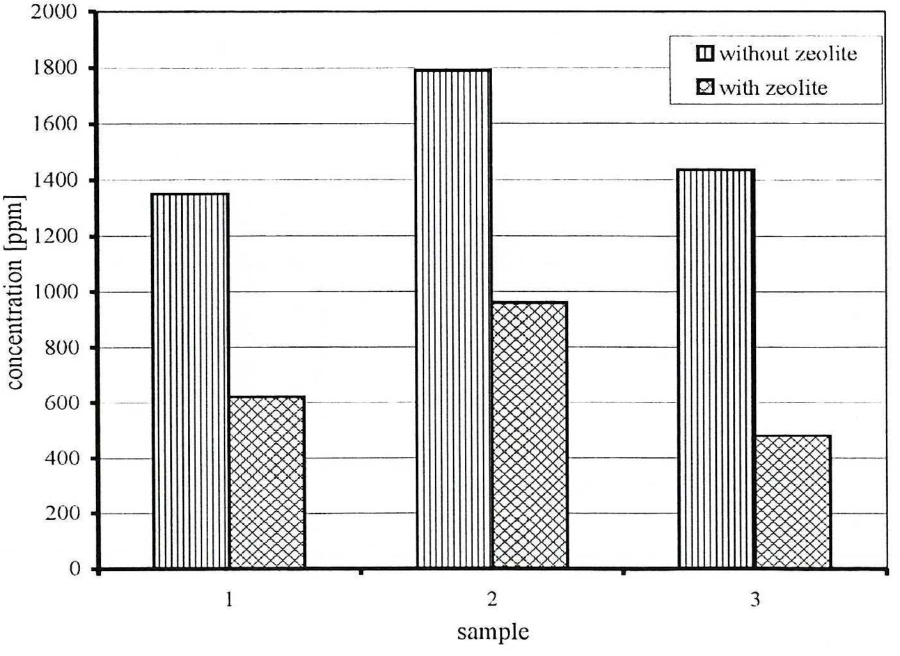

Fig. 5. CO concentration reduction in fluidized combustion

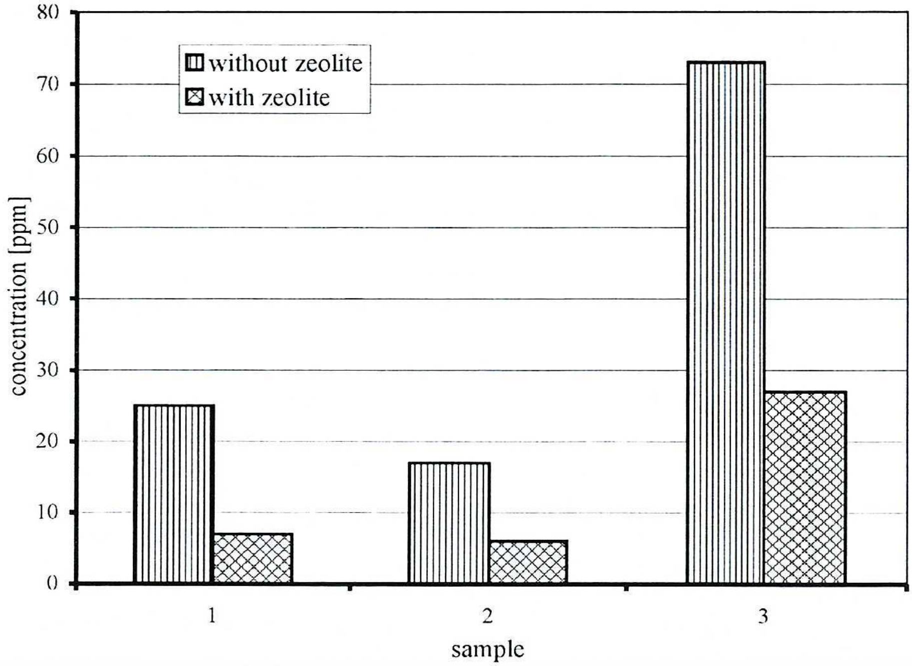

Fig. 6. NO concentration reduction in fluidized combustion

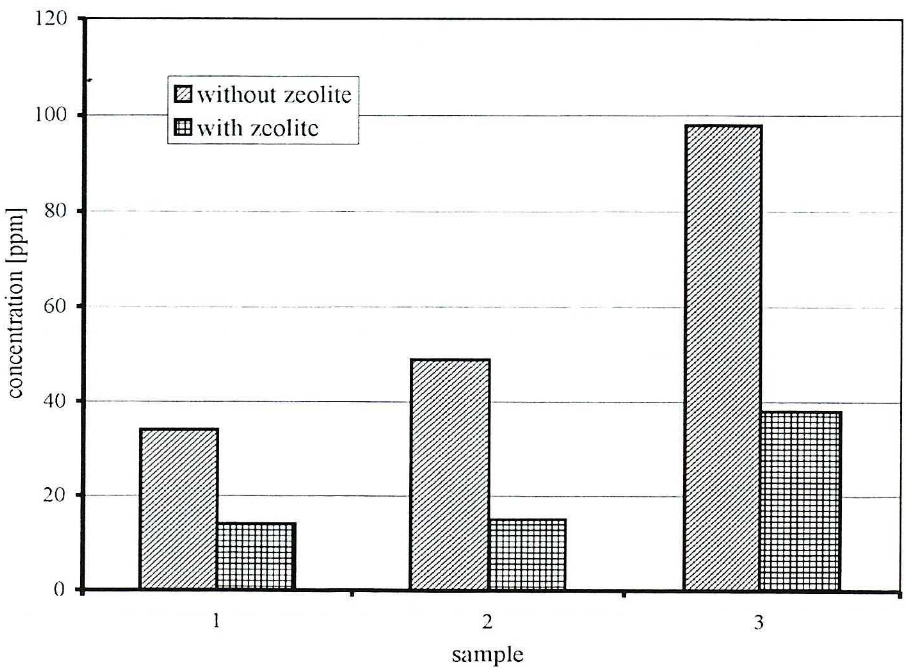

Fig. 7. SO_2 concentration reduction in fluidized combustion

The application of natural zeolites as a fluidized bed was the reason why the reduction of CO reached up to 50%, NO and SO_2 up to 60%.

CONCLUSION

In according to the experiments carried out, it was found that the fluidized bed combustion can be used for destruction and utilization of oily wastes from metallurgical works.

Fluidized bed combustion of oily wastes seems to be a more efficient way comparing to direct combustion because the process is effective even without any preliminary treatment of these wastes.

Calculations and estimations showed that, from energetical point of view, oily wastes from rolling-mill process are a potential source of energy in the amount of 50 GJ annually.

Taking into account the results of pollutants concentration during the fluidized bed combustion technology, one should notice that this technology may be friendly for natural environment.

Application of natural zeolite beds in the fluidized combustion technology of liquid post-rolling wastes reduce concentration of gaseous toxic components in the combustion gases due to absorption by zeolite materials.

The laboratory work reported in this paper is a part of a larger program utilizing a small laboratory fluidized combustor with zeolite beds to examine possibilities of control and reducing exhaust gases emissions from combustion of calorific and low calorific solid and liquid wastes.

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