PARTIAL FAST PYROLYSIS OF TURKISH COALS

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ABSTRACT: Pyrolysis plays an important role in providing the power, chemicals. Refining industries containing pyrolysis and gasification mainly need clean fuels. In this projected work, economically competitive and environmentally conscious, fast pyrolysis technology option was investigated in order to produce electricity, fuels and chemicals. The retort partial pyrolysis process for Sirnak asphaltite and Gediz lignite uses a horizantal kiln type furnace as the heat carrier solid coal ash and flue gas are used. The process can accept shale fines. The oil yield varies, averaging approximately 17-18% on raw coal basis. The oil contains 22–25% low-boiling fractions. The process produces only small amounts of phenol-contaminated water at low concentrations. Further processing of the water is inexpensive. Most of the phenolic compounds generated in the process remain in the oil and may be easily removed by water extraction. Gaseous yield is collected out from spent coal in the furnace. Lime and other alkalis were used for desulphurisation of gaseous products and oil fractions.

1. INRODUCTION

Lignite consumption in energy production is increasing in parallel with growing energy needs today. In terms of reserve and production quantities of high quality lignite, natural resources are limited. The significant amount of electricity is produced primarily from coal in the world [Minchener, 2007; EIA, 2012].

The revised almost 219TWh total electricity in 2013, were produced primarily from imported natural gas and domestic coal in Turkey [TKI, 2012; TTK, 2012]. The total amount of asphaltite resource in reserves and production in Şırnak City are over 82 million tons of available asphaltite reserve and near 500 thousand tons per year, respectively [TTK, 2012]. The most effective and cost-effective technologies are needed for clean coal products in today's modern technologies [Çulfaz et al.,1996; Reimers et al.,1991; Tosun et al., 1994; Wheelock, 1979; Yoon, 1991]. Turkish coal industry needs noble gasification technologies and high gasification performances at lower cost with various types of local coals regarding researches. The most effective and cost-effective technologies are needed for clean coal products in today's modern technologies [Tosun, 2012; Tosun, 2013; Bell et al., 2011]. Turkish coal industry needs specific tests in order to measure gasification performances of various types of local coals regarding standard qualification tests. There are lots of signs for the production of bio-masses and lignites in industrial many fields even using regular high capacity biomass of cellulosic wastes. Processing technologies using biomass should be under contribution to the fuel side [Tosun, 2013]. On the nature and characteristics of the medium as base lignites are distinctly determined. In the view producing high value cleaned products, pyrolysis and gasification of lignite are managed for this purpose.

Depending on advanced technological developments in energy production the low quality coals needed the most economical technologies and even in order to make it possible to produce coal-derived products. Compliance with environmental norms of coal pyrolysis or gasification of various types of coals, feasible combustion systems and energy production facilities are needed in today's modern technology, also enable the production of liquid and gaseous coal fuels [Tosun and Ciragoglu, 2013]. However, raw materials and chemical nature of them requires a variety of adaptation methods. For this purpose, universities and industry needing to work together to provide the basic information required in pilot scale. Thus, the higher performance can be achieved by a certain mixture of solid fuel additives. A preferable advanced design in pyrolysis could produce clean coal fuels in the local site of the country so significant that needs to obtain the highest quality coal fuels.

1.1. Pyrolysis to Coal Oil and Char

Considerable research on coal pyrolysis and gasification has been conducted over the years, but the pyrolysis results are widely dispersed because of the complex chemistry of coal [Kajitani et al., 2006]. Time related coal-pyrolysis modeling assumes basically first-order kinetic equations, or less sensitive for heating rate [Shadle et al., 2001]. The other distributed activation model is dependent on the heating rate. The last two more advanced models need three and four constants, respectively, which basically depend on the coal properties but also cover to some extent, the effect of heat-and-mass transfer phenomena [Sharma et al., 2008]. That is the reason for the different values of the activation energy and pre-exponential factor cited in the literature and the lack of generally valid data. The same situation exists in the case of coal-char gasification. The reaction rate of char is influenced mainly by chemical and physical factors, which include coal type, catalytic effect of the ash and the specific surface area of char, which changes during the reaction course with the development of internal pores, and finally, their destruction. In the case of the scaling-up procedure, the uncertainty of a complex model of the reacting system may be very high and it is reasonable under some conditions to use a methodology based on quasi-equilibrium conditions, which can be reflected at a larger scale. This study examined the high sulfur and ash types of Gediz, Soma lignite, Sirnak asphaltite and lignite. The representative samples were taken from local areas of the lignites. Fundamentally, the conditions regarding better desulfurization way, high quality lignite oil production, high value light oil, coal tar and gas products were determined at the goal of high fuel producing yield. For this purpose, further washing of Gediz, Soma lignites, Sirnak asphaltite and lignite may improve pyrolysis products.

1.2. Partial Fast Pyrolysis

The country needs the cleanest fuel to be produced providing the essential oils and gases. For this reason, partial fast pyrolysis at shorter times among 30s and 2 minutes of Kütahya Gediz, Soma lignite, Şırnak asphaltite [Tosun, 2014] at coarse size fraction may be so feasible at the side of cost and production high amount of oil, gaseous fuels instead of importing natural gas. Advanced coal washing of Turkish coals may not be feasible. However, fast pyrolysis and following combustion or gasification in the same chamber of Turkish coal can be managed [Çakal et al., 2007; Schurtz and Fletcher, 2009; Jess, 2009].

2. MATERIALS&METHOD

This project approach assumes basically that the process itself, with all specific features, is a decisive factor for the path of the reactions of coal decomposition. Therefore a static model of fast pyrolysis and coal pyrolysis was developed. It is based on the assumption that the final process temperature is a decisive factor for the required volatile-matter content in the char being in a quasi equilibrium state with respect to the gas temperature. Instead of fluid bed pyrolysis, packed bed pyrolysis of coarse size coals is governed by chemical reactions on particle gas reactions. Partial fast pyrolysis rates were higher so that mass diffusion rates of gaseous materials to coal particle fundamentally control reaction kinetics.

A kiln reactor was used in coal pyrolysis heated till 600 °C with a rate 7-10°C/min by fuel. The process was tested at a scale of 0.2–0.3 kg/h; collecting operational and design data to build an industrial installation. A technological diagram of the fast coal pyrolysis process developed unit is made. Thermal destruction almost observed at temperature increase from 350 or 400°C with a desulfurization rate of 60-70% and with simultaneous dilution of oil products by condenser distillate. To achieve this, it is necessary to create conditions of internal circulation without the transported coal and char in rotary kiln, where the average concentration of solids amounts to 10- 50 gr/l, i.e. the conditions for residence time are long enough for the thermal decomposition of coal and intensive gas mixing so enhancing mass and heat transfers.

Table 1: The format for table heading.

Coal Type	Ash,% ADB	Moisture,% ADB	TotalS,% DB	Volatile Matter,% DAB
Şırnak Asphaltite	46.3	0.1	6.7	62.6
Kütahya Gediz	22.0	1.7	3.6	42.7
Soma Kısrakdere	13.8	14.0	2.2	40.4

Laboratory scale fast pyrolysis installation of coal was made simply as illustrated in (Figure 1). Tube silica bottom layer was filled with fine coal sample and silica tube covered by clay cover. To achieve this, it is necessary to create conditions of internal circulation without the transported coal and char in tube, where the average concentration of solids amounts to 0.3- 0.5 gr/l, i.e. the conditions for residence time are long enough for the thermal decomposition of coal and intensive gas mixing so enhancing mass and heat transfers.

Thermal gasification commenced by fuel burning into the packed coal heap firstly and then CO_2 gas evolution followed and circulated into the silica tube for three minutes. It is observed a temperature increase from 100 to 800°C without fuel addition, steam and air in the tests. Gaseous products with simultaneous dilution of oil products by condenser distillate are collected. To achieve this, it is necessary to create conditions of internal circulation without the transported coal and char in tube, 6-12% oil yield recoveries were observed at the end of partial fast pyrolysis.

Pyrolysis rate shows variation of substitution rate of N_2 gas with time at (a) inlet cell and (b) stack outlet cell for each case.

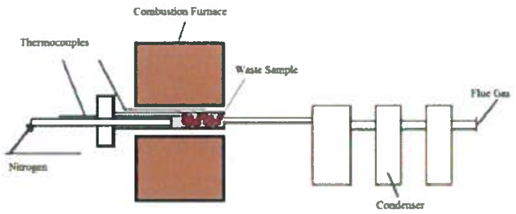

Figure 1: The format for figure heading.

Gas permeability of coal porous layer was almost equal to the blank condition without the sample. Wide size distributed coal also exhibited gas permeability, though the performance on gas permeability was lower than that of single sized coarse coal porous layer. From these results, we employed coarse coal as a porous layer that constitutes 3 mm sized coal used in the test.

3. RESULTS AND DISCUSSION

In the fast pyrolysis experiments with addition various alkaline solids, reactor temperature changed to 650°C and lignite samples are mixed only by %10 alkali. Products received from pyrolysis of coal specimens were subjected to analysis for sulfur hold-up determination. Test results of pyrolysis by alkali are seen in Figure 2. In the partial fast pyrolysis experiments with addition hydrated lime, reactor temperature changed between 400°C and 650°C and lignite samples mixed only by %10 lime at 30s. Products received from pyrolysis of coal specimens were subjected to analysis for sulfur hold-up determination. Test results of pyrolysis by lime are seen in (Figure 3).

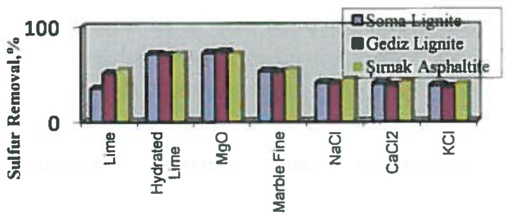

Figure 2: Solid Desulphurization in Tube pyrolyzer of Turkish Lignites used in coal pyrolysis process.

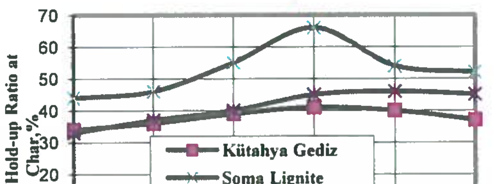

Figure 3: Comparison of desulfurization with solid lime addition at %10 weight rate to pyrolysis chamber with Turkish Coal.

From the point of view of pyrolysis experimentation, Şırnak asphaltite calorific value was significant. That chars quantity in the pyrolysis chambers for biomass, lignite and coal samples were determined for different source evaluation and reduce the effect of ash content of coal samples in order to optimize pyrolysis rates of lignite samples. As given in (Figure 4) gas and oil yields for lignite and coal samples were slightly similar, oil yield was lower for coal. In the pyrolysis experiments with different particle size fractions of coal specimens, at reactor temperature changed to 600°C and lignite samples mixed only by lime at 10% weight rate. Products of fast pyrolysis of coal specimens were subjected to analysis for yield determination. Test results of gasification of Turkish lignites are seen in (Figure 5).

In the pyrolysis experiments, the experimental conditions are calculated on the basis of the weight change in the ambient state. So neither the contained water vapor nor the condensing hydrocarbons are taken into account. Pyrolysis liquid and gaseous products of Sırnak asphaltite may equal to 5–20 g tar/m^3 and 5–10 g/m^3 of benzene, toluene, xylene in unit process gas. Moreover, Figure 5 showed that oil yield of coarser coal was lower than that of fine coal samples of minus 0.1 mm, at about 27% weight. Gas yield was containing mainly steam and CO_2 in the pyrolizer and the weight amount of gas was remained between 37 and 40% depending on water content of coal samples. However, these components increased by decrease the particle size to 100 micron and oil yield was remained low 12% weight. Those values provided advantageous higher carbonaceous content to be converted to gas in pyrolysis stage. Partial fast pyrolysis tests were carried out for Turkish lignite and Sırnak asphaltite at 3mm size distribution and optimized gas inlet of 0.3l/min.kg coal. The effect of pyrolysis time at 700 °C in Tube Fast

Pyrolysis Process of Turkish coals were tested with ranging from 10s to 4 minutes over oil yield rate. As seen from Figure 6 it showed that pyrolysis time between 30s and 60s were sufficient in partial pyrolysis of Turkish lignite and coals. Partial Oil yields of Şırnak asphaltite across to temperature were shown from (Figure 7) and even other lignites showed similar trend, the higher oil yields at higher pyrolysis temperatures over 600°C. Furthermore, the results of partial pyrolysis exhibited the similar high gas yields depending on CO_2 gas at the gas outlet with the same apparatus. That conversion rate remained among 38-42%. Even it was observed that increased the gas's calorific-value by 320–1200 kJ and, in total, allow one to obtain a gas of calorific value of up to approximately 5700 kJ/m^3 for Sirnak asphaltite. Therefore it was supposed that porous coal layers, especially porous alkali and catalysts exhibit sufficient gas permeability at least for the gases of chemically inactive and sufficiently small in particle size.

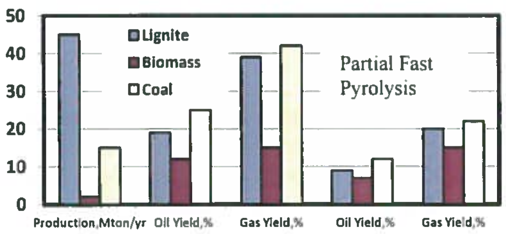

Figure 4: Comparison of lignite, coal and biomass in fast pyrolysis of coal, partial fast pyrolysis.

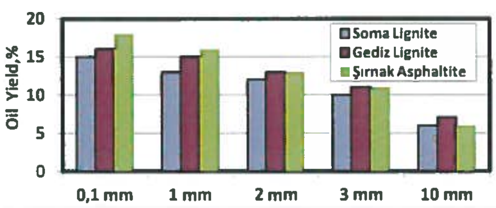

Figure 5: Effect of particle size of coal over oil yield rates in Tube Fast Pyrolysis process of Turkish Coal and Lignite used.

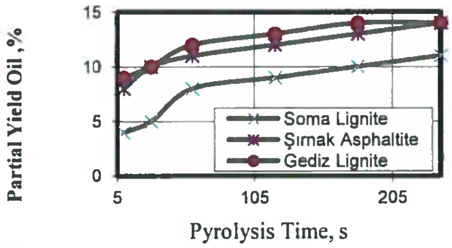

Figure 6: Effect of Pyrolysis Time over Oil Yield rate at 700 °C in Tube Pyrolysis Process of Turkish coals used.

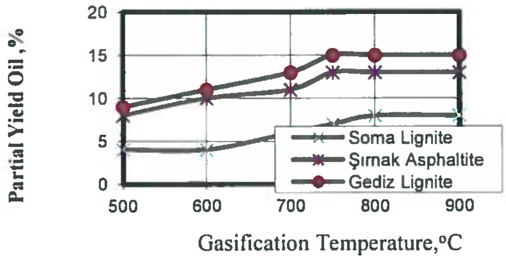

Figure 7: Effect of Pyrolysis Temperature over Oil Yield rate in Tube Pyrolysis Process of Turkish coals used.

4. CONCLUSIONS

Partial fast pyrolysis of different types of Turkish coals was successfully processed in terms of desulfurization and even reduction of volatile matter. At higher rates of carbonization of different types of Turkish lignite could be obtained from the tests using low flow nitrogen inlet at 500°C. It has been clearly determined that partial evolved CO_2 and steam much beneficial in pyrolysis of different types of Turkish coals. It was also distinctly ascertained that low temperature gasification with % 16 flue gas was yielded efficiently in partial fast pyrolysis of Şırnak asphaltite. Şırnak asphaltite should be cleaned and high ash content reduced char and oil yield in fast pyrolysis.

Benefaction from Turkish lignites in the various parametric pyrolysis systems, in order to receive clean energy clean liquid and gaseous products must be generated in low temperature pyrolysis. It is also advised that the high amount of formation of flue gas will be managed high pyrolysis temperatures over 700 °C and extracts more environmental friendly gaseous products.

In the research works production of clean energy with the design of the addition of high-quality coal biowaste mixtures are processed and biomass fuels could be an alternative clean fuel sources. Clean energy sources may be supplied in South East Anatolian region in Turkey. Hence, those clean alternative resources will further enhance the industrial development in the region.

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