Coal Gasification of Şırnak Asphaltites – Coelectricty Production by Coal Bed Methane, Asphaltite Gas and Biogas

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Abstract— **Turkish Energy Agency adopting clean coal to fill the immediate energy gap would also help us set the right example internationally and encourages the meeting of emissions targets globally. Countries such as China, India and the US produce more than 30 times more carbon emissions than the UK and must be encouraged to clean up their coal powered plants. Clean coal technology is the best solution for the short-term if we are to avoid overdependence on imported gas. It can reliably close the Turkish immediate energy gap, within a diverse generation portfolio that secures energy supply. Because coal can be stockpiled, prices remain stable. Indeed, they have remained relatively stable for decades. Clean coal provides the means to achieve the objectives set out in the energy review. The energy review is just the first step. The power plant firms must take serious actions now, or the costs will go up.**

Gasification plays an important role in providing the power, chemical and refining industries with economically competitive and environmentally conscious technology options to produce electricity, fuels and chemicals. The fluidized gasification process for Sırnak asphaltite uses a vertical 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 22-28% on raw coal basis. The oil contains 15–20 % 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 fluidized 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.

Keywords- coal gasification, pyrolysis, desulfurization, coelectricity production, lignite pyrolysis

I. INTRODUCTION

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 as given in Table 1[1, 2]. The highest amount of natural energy sources in Turkey, as the most economical means, and also to provide high value-added products for the benefit of the country will make a very positive growth and employment. Especially, lignite natural resources, one of primary energy sources with the annual total production of 72 million tons (+2,9 million tons hard coal) promotes to the highest priority research and development of processing in Turkey. A specific evaluation is required for lack of qualified sources in the local area.

TABLE I. ELECTRICITY PRODUCTION FROM COAL IN THE WORLD .

South Africa 93%	Poland 87%	PR China 79%
Australia 78%	Kazakhstan 75%	India 68%
Israel 58%	Czech Rep 51%	Morocco 51%
Greece 54%	USA 45%	Germany 41%

The almost 211TWh total electricity in 2011, Turkey were produced primarily from imported natural gas and domestic coal (Figure 1) [3,4]. The total amount of asphaltite resource in reserves and production in Sırnak City are over 82 million tons of available asphaltite reserve and 400 thousand tons per year, respectively [5]. The most effective and cost-effective technologies are needed for clean coal products in today's modern technologies [5-9]. Turkish coal industry needs specific tests in order to measure gasification performances of various types of local coals regarding standard qualification tests.

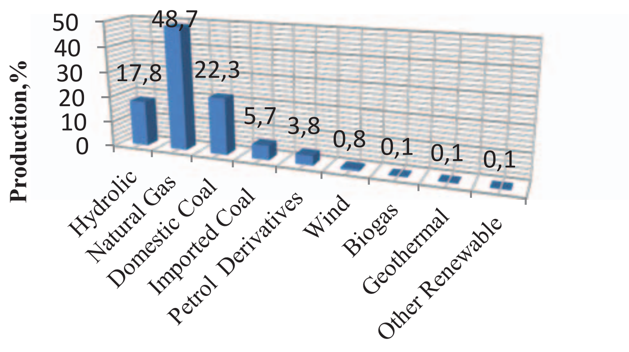

Figure 1. Electricity Production from Primarily Resources in Turkey and Comparison of Lignite and Imported Natural Gas in Turkey revised regarding 2011 coal report data, Eurocoal, EIA and TKI Reports[1-5].

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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 [10,11]. 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. 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. 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. 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.

A. *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 [10-16]. Time related coal-pyrolysis modeling assumes basically first-order kinetic equations, or less sensitive for heating rate[17,18]. 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 [19]. 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 [20]. 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.

B. *Gasification*

On the other hand, the gasification of circulated char is mainly chemically controlled due to the relatively short residence time of the gas [17, 18]. Additionally, the characteristic feature for a given circulating fluid-bed reactor is a very narrow range of operational residence time, both for the gas and coal, which allows us to use the quasi-equilibrium approach. The model developed reflects the kinetic processes (transport phenomena of coal species, reaction rate) by constants of the developed equations, which depend mainly on the coal properties [21, 22].

This 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 char gasification 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. To achieve this, it is necessary to create conditions of internal circulation of the transported coal and char in a riser, where the average concentration of solids amounts to 0.05 – 0.15 m^3/m^3, i.e. the conditions for residence time are long enough for the thermal decomposition of coal and intensive mixing so enhancing mass and heat transfers.

II. PROJECT WORK

In this research, representative specimens the different types of Turkish lignite Şırnak asphaltite and lignite coals Kütahya Gediz, , Soma Kısrakdere were crushed and comminuted to minus 1mm size by controlled screening. Air dried samples of 1-2 kg from each different coal types were prepared and sealed in nylon bags. Proximate analysis of Turkish lignite and hard coals used in the experiments are given in Table 1.

TABLE II. PROXIMATE ANALYSIS OF TURKISH LIGNITES. (ADB:AIR DRIED BASE. DB:DRIED BASE, DAB:DRIED ASHLESS BASE).

Coal Type	Ash,% ADB	Moisture, % ADB	Total S,% DB	Volatile Matter,% DAB
Şırnak Asphaltite	49.3	0.1	8.1	62.6
Şırnak Lignite	29.3	18.1	3.1	52.6
Kütahya Gediz	22.0	1.7	3.6	42.7
Soma Kısrakdere	13.8	14.0	2.2	40.4

Screen analysis of Turkish lignite samples were made by standard Tyler Screens and particle size distributions and normal distributions of lignite samples are respectively illustrated from Figure 2. Specific surface area of hard coal samples was 1760 cm^2/gr determined by benchmarked Rigden flow meter and highly sufficient in order to react with gaseous reactant. As seen from Figure 2, 80% of weights of samples were 0.3 mm. Coal particles in lignite samples were mainly distributed between 200 and 600 μm size fractions. Polarized 80X magnified pictures of coal samples of lignite are shown in Figure 3. Main bituminous structure is widely distributed and pores structures are associated with ash minerals. Coarse silicate minerals are also seen in the picture.

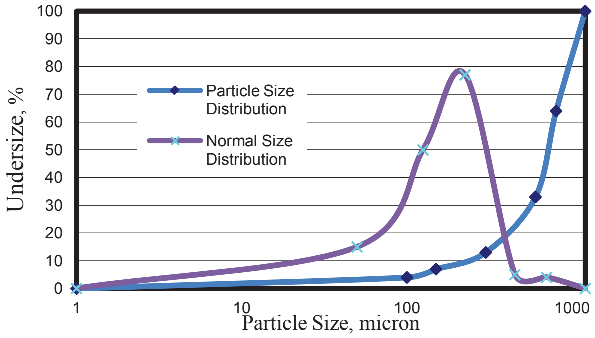

Figure 2. Particle Size Distribution and Normal Size Distribution of Turkish Lignites used in coal gasification-pyrolysis process.

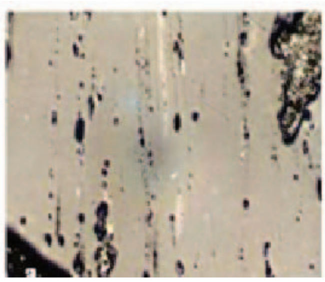

Figure 3. Polarized microscopy of coal sample and Distribution of pores and minerals in Lignite used.

A circulating fluidized-bed reactor was used as a coal pyrolysis reactor. The process was tested at a scale of 2 – 3 kg/h: collecting operational and design data to build an industrial installation. A technological diagram of the coal gasification-pyrolysis process development unit is presented in Figure 4.

III. Results and Discussions

In the pyrolysis experiments, effect of addition hydrated lime over pyrolysis and gasification was determined, reactor temperature changed between 400^{o}C and 650^{o}C and lignite samples mixed only by %10 weight rate hydrated lime. 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 5.

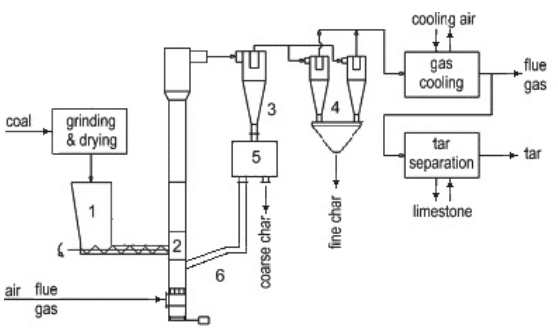

Figure 4. Fluidized bed gasifier of Turkish Lignites used in coal gasification-pyrolysis process.

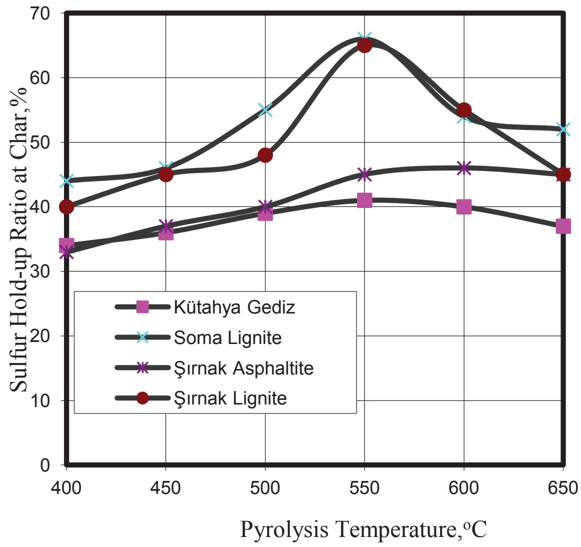

Figure 5. Comparison of desulfurization %10 lime addition to pyrolysis chamber with lignite

From the point of view of gasification 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 and gasification rate of lignite samples. As given in Figure 6 gas and oil yields for lignite and coal samples were slightly similar, oil yield was lower for coal.

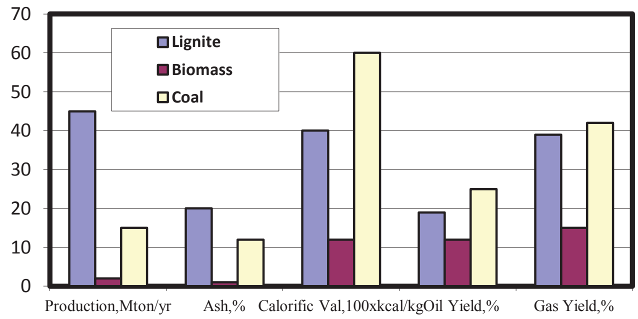

Figure 6. Comparison of Probable Evaluation of Turkish Lignite, Hardcoal and Biomass in pyrolysis, coal-gasification process, partial pyrolysis of biomass and biowaste, prepared regarding that project work.

In the gasification experiments with different particle size fractions of coal specimens, at reactor temperature changed to 600^o and lignite samples mixed only by lime at 10% weight rate. Product gas and oil yields in gasification of coal specimens were determined and compared on yield amount base. Test results of those yields in gasification of Turkish lignites are seen in Figure 7.

In the gasification experiments, the experimental conditions are calculated on the basis of the gas composition 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 lignite may equal to 5 – 20 g tar/m^3 and 5 – 10 g /m^3 of benzene, toluene, xylene in unit process gas (Figure 8). These components increase the gas's calorific-value by 390 – 1100 kJ and, in total, allow one to obtain a gas of calorific value of up to approximately 5900 kJ/m^3 for Sirnak asphaltites. Char yield of Şırnak asphaltite and other lignites increased at higher gasification temperatures (Figure 9).

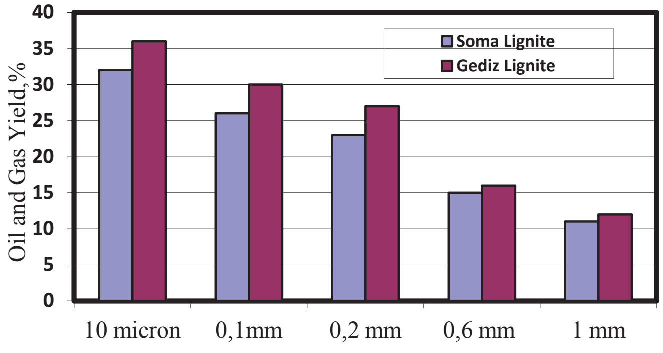

Figure 7. Effect of particle size of coal over Yield rates in Fluidised Bed Pyrolysis process of Coal and Lignite used.

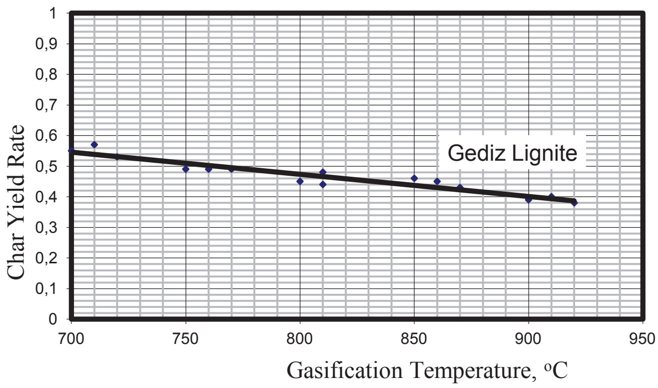

Figure 8. Effect of gasification temperature of coal over Char Yield rate in Fluidised Bed gasification process of Coal and Lignite used.

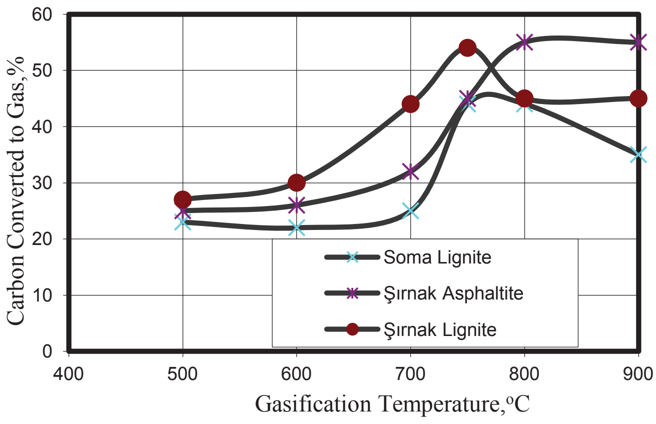

Figure 9. Effect of gasification temperature on coal conversion and gasified yield rates in Fluidised Bed gasification process of Coal and Lignite used.

The high amount of formation of flue gas will be managed by gasification. However, in this study at slow heating rates of over 5^{o}C/s temperatures could be provided and sufficiently carbon gasification rates were remained limited to56% rate.

IV. Coelectricty Production by Coal Bed Methane, Asphaltite Gas and Biogas

According to the proposed project studies over coal bed methane drainage, it is calculated that at almost 40% drainage performance methane gas could be received in the mine site and methane gas collected at average near 2,7m^3/ton coal. Coal seam gas production may reach to 200.000 m^3/yr. Biogas production potential in Sırnak City and close local area is almost 5 % of the methane produced in coal seam. Hence optimized resource usage in co electricity production could just be managed by gasification plant. At projected capacity at 100.000 tons of coal per year can manage proposed 40% gas yield and can produce almost equivalent 50 million m^3/yr coal gas. However, all the gaseous products are co-burned in internal combusting generator converting heat to 35MWh electricity per year.

V. Conclusions

The country needs the cleanest fuel to be produced providing the essential oils and gases. For this reason, Kütahya Gediz, Soma lignite, Sırnak asphaltite and lignite locally successfully tested. Advanced coal washing of Şırnak asphaltites, pyrolysis and gasification of clean products could be managed at the projected way. The production of liquid and gaseous fuels may improve local industry in energy aspect and the proposed development in the Southeastern Anatolian region may further improve the diversification of fuels in local energy market.

Pyrolysis of different types of Turkish lignites was succesfully processed in terms of deashing and desulfurization and even reduction of volatile matter.

The specimens of different types of Turkish lignite, Şırnak asphaltite and lignite were greatly desulfurized at 46% and 67% rate by lime, respectively. Soma Kısrakdere lignite was desulfurized at 66% rate by lime.

For cleaning of Şırnak asphaltite and lignite the heavy media devices were used for washing to deash coal to a lower ash contents than 15% for clean coal products. Those samples were subjected to presented gasification process. While scale up plant projected, proposed pyrolysis and gasification processes in order to receive high amount of oil yield and the highest level of efficiency in the gasification of carbonized gas was managed over 700^{o}C and below 800 ^{o}C. Between these temperatures, high liquid and gas fuel production efficiencies were determined at the 55% and 57% values for Şırnak lignite and asphaltite, and other one optimized pyrolysis parameter was the particle size distribution fed to the furnace was ranged among 0.2 mm and 10 microns for Turkish lignites.

However, lignite-based technologies are examined on the basis of raw materials various projects on gasification of coal resources successfully carried out [23-27]. Even the projects contributing to the side of the forest waste biomass as raw material, cellulosic waste resource can be processed with the lignites [28]. Some extent mixing was carried out in order to improve the pyrolysis quality of Şırnak asphaltite and lignite so that ash and sulfur contents of lignite samples would be so lower than the best gasification conditions.

Şırnak asphaltites could be cleaned and high ash content of Turkish lignite reduced char and oil yield in pyrolysis. The fluidized gasification process for Sırnak asphaltite uses a vertical 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 22-28% on raw coal basis. The oil contains 15–20 % low-boiling fractions.

At higher rates of desulfurization of different types of Turkish lignite could be obtained from the tests using lime it has been clearly determined that 10% weight rate addition lime was much beneficial in desulfurization of different types of Turkish lignite in pyrolysis and gasification. In another study, it was also distinctly ascertained that marble waste fine containing approximately %6 magnesia was much efficient as a desulfurizing agent in partial pyrolysis and pyrolysis of Turkish lignites with marble wastes decreased sulfur contents of chars and liquid products at 68-74% [29]. Magnesia content was efficient as hydrous lime but much more advantageous in absorption stage of gaseous medium [29].

Benefaction from Turkish lignites in the various burning systems, in order to receive clean energy clean liquid and gaseous products may be generated in low temperature pyrolysis and gasification. It is also advised that the high amount of formation of flue gas will be managed by fast pyrolysis. However, in this study at slow heating rates of over $5^oC/s$ temperatures and over 700 ^oC, high amount of extracts and more environmental friendly gaseous products could be produced.

In this research work, use of high-quality coal- biowaste mixtures and biomass fuels were easily processed. Production of clean energy with the suitable design could be managed. A proposed alternative offered to clean fuel resources. Clean energy resources may further be highly demanded in South Eastern Anatolian region in Turkey. Hence, those clean alternative resources will further fill that energy gap and enhance the industrial development in the region.

By pyrolysis and gasification gas cleaning and CO_2 capturing may be easily performed. Economic advantages of the sequestering the CO_2 are defined for economical view by coal bed methane gas production and green energy production [30,31]. Also economic view of designed work comprising sequestering the CO_2 into the coal bed may improve coal bed methane production in coal mine in Şırnak.

Research institutions mainly should search characteristics of various lignite-biomass mixtures-to-date processes and improve advance technological applications. Advanced processes may carry out performance tests, depending on the nature of the raw materials necessary to prompting clean energy.

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