

Environmental Pollution Reduction in Cement Industry for Co Combustion of Waste Tyre and Coal as a Fuel

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Abstract: In recent years, there are several problems encountered in waste management system particularly waste tyre as well as coals. The energy generation on incineration provides large amount of polycyclic aromatic hydrocarbon (PAH) emissions which is the cause of major environmental threat. Therefore, the combustion of coal and tyre were carried out in cement industry in order to generate heat energy at 1300°C and the only remaining residue (steel powder) to enhance the strength of the cement. At the outset, the particle size of coal and tyre was cut into 63-75 and 180-212 µm respectively. Combustion experiments were conducted using Nelson reactor under controlled conditions in presence of air and also in presence of nitrogen gas (INOX) atmosphere. The temperature range was varied from 300-1300°C and several fuel mass loading in the furnace, expressed in terms of bulk equivalence ratios in the range of 0.7-2.4. At fixed bulk equivalence ratios, as the furnace gas (Air) temperature increased the polycyclic aromatic hydrocarbon yields from both fuels decreased drastically, while the CO₂ yields increased. At the highest temperature around 1300°C, the effluent of combustion of both (coal and tyre) fuels was practically devoid of polycyclic aromatic hydrocarbon (PAH) (at a detection limit of 0.3 µg of a PAH component/g of fuel burnt). In order to understand the rate of thermal effect and morphology of co combustion material (coal and tyre), the preliminary results are very essential to explore. Therefore, the thermo gravimetric analysis (TGA) and environmental scanning electron microscopy (ESEM) were carried out and results of coal and tyre mixture at various temperature conditions will be highlighted.

Keywords: Environmental Emission, Cement Industry, Carbon dioxide, polycyclic aromatic hydrocarbon (PAH), Nelson reactor.

I. INTRODUCTION

Coal is the predominant fuel for power generation in the world. India alone produces 1.5 and consumes approximately 1.0 billion of coal yearly for power generation. Thus, a thorough study of the emissions of coal is warranted. Waste tyres, on the other hand, are generated by the billions every year, with India alone discarding an estimated quarter of a billion tyres, but they are not currently used for energy generation to any significant extent. Instead, they are either land filled or stored in tyre dumps, creating health problems and fire hazards. Because of their high heating value (29-37 MJ/kg, which is higher than most coals), however, waste tyres are being considered as an attractive potential fuel. With an average weight for tyres of 10 kg, a total of 2.5 million ton of tyre-derived fuel can be produced in India per year amounting to 0.5% of the coal consumption. In addition to this amount, more fuel can be deduced from existing tyre stockpiles, and the yearly electric energy production potential from tyres could reach 2% of that from coal.

While pulverized coal is widely used in most utility fired boilers, pulverized rubber from waste tyres is still a costly proposition, mainly because it is made desired smaller sizes using cryogenic processes that are currently used to produce it and the small scale of existing operations. According to certain sources, the current price of pulverized tyres is currently 3-5 times higher than that of coal (Rs. 9000-15000 vs Rs.3000/ton). This price difference can be bridged, however, if cost effective large scale tyre grinding processes

are invented and/ or if higher fees are implemented. First of all, the waste tyre will be grinded after dipping into liquid nitrogen (-196°C). This will avoid the high cost of building dedicated tyre-to-energy combustion facilities. Therefore the combustion and emissions of both fuels in pulverized form will be examined.

Six industries have been identified as energy intensive industries globally: Cement, Aluminum, Fertilizer, Iron and Steel, Glass and Paper [1]. Cement industry consumes about 4 GJ per tons energy of cement produced. Indian cement industry accounts for 10.3 % of total fuel consumption in the manufacturing sector [2]. Out of total, about 50% carbon dioxide is generated during calcinations and remaining during the combustion processes [3]. Cement industry had emitted 43 million tCO₂ in 1990 that has increased to 59 million tCO₂ in 1995. In 1995, energy use contributed 40% of total cement sector emissions while the remaining was due to calcinations process [4]. Worrell et al.,

[5] have carried out an in-depth analysis of the US cement industry. They found that the use of blended fuel is a key cost-effective strategy for energy efficiency improvement and CO₂ emission reductions. Xiang - Guo et al., [6] have performed experiment on combustion of waste tyre, high ash coal and tyre-coal blends with 10, 30 and 50% waste tyre were investigated by means of thermogravimetric analysis (TGA). They found that incorporation of waste tyre can improve the combustion characteristics of high ash coal, especially the ignition performance and the peak weight loss

compared with the separate burning of waste tyre and coal. This indicates that the co-combustion of waste tyre and low qualities coal as fuel is feasible. Giere et al., [7] have studied a mixture of 95 wt. % coal plus 5 wt. % Tyre-Derived Fuel (TDF) in the form of shredded automotive tyres by combusting it in a stoker boiler under plant conditions. They found that emissions of CO decreased slightly, whereas those of NO_x, SO₂, and total particulate matter remained virtually unchanged. Katsioti et al., [8] have stated the prerequisites for using of TDF as a supplement fuel for the clinker production.

The compressive strength of cement produced was measured. In this specific study 6% of the total fuel used was TDF. It was concluded that no apparent problems occurred from the use of TDF as a supplemental fuel in the clinker burning. Kemm et al., [9] describes a Health Impact Assessment (HIA) of a proposal to change the fuel used in a cement plant. It concludes that there is no change in emission of tyre burning. It was carried out to support a health authority, known as a Primary Care Trust (PCT), in preparing its response to consultation under the Integrated Pollution Prevention and Control (IPPC) process.

In this study, combustion of waste tyre, coal and tyre-coal blends of 1%, 3% and 6% were investigated by means of Thermogravimetric Analysis (TGA) which was carried out at 10⁰C/min in Thermogravimetric Analyzer and in the range from 50⁰C to 900⁰C i.e. Thermogravimetric Analysis (TG), Derived Thermogravimetric Analysis (DTG) and Differential Thermal Analysis (DTA). For blends of coal and waste tyre, no interactions between blend components are observed in TGs. However, for DTG, comparatively difference was seen that could be related to a certain degree of interaction between the components. The co-combustion of coal and waste tyre cannot be predicted from the weighted sum of the blend components. The incorporation of waste tyre can improve the combustion characteristics of coal, especially the ignition performance and the peak weight loss compared with the separate burning of waste tyre and coal. This indicates that the combustion of waste tyre and coal as fuel is feasible. With this in view, the study attempts to investigate the effect of percentage blending waste tyre with coal.

II. EXPERIMENTAL STUDY

Fine powder of tyres was prepared by shredding and grinding of waste tyres. Coal powder was prepared by crushing the coal pellets. The material whose thermal decomposition was studied consists of waste tyre, coal and tyre-coal blends of 1%, 3% and 6%. The percentage of waste tyre refers to weight of coal. Waste tyre and coal was mixed properly. The combustion characteristics of coal, waste tyre and tyre-coal blends were determined in Perkin Elmer TGA 7 Thermogravimetric Analyzer. Sensitivity variation was ± 0.1 μ g. The specimen size was approximately 1 to 100 mg. The temperature variation of furnace was from room temperature 25⁰C to 1000⁰C. The heating rate of sample was varied from 0.1 to 200⁰C. The furnace temperature was increased from 50⁰C to 900⁰C at 10⁰C min⁻¹ under Nitrogen atmosphere.

Then sample was cooled to room temperature under Nitrogen atmosphere. The weight of sample was monitored

continuously as function of temperature. The TG, DTG and DTA were performed.

III. RESULT AND DISCUSSION

The analysis results were obtained in the form of plot of temperature vs. weight loss with Heat Flow Endo Down. Figure 1 shows Thermo gravimetric Analysis (TG) of Coal, Tyre, and Tyre blended with coal. Figure (1a) shows the typical TG profile of coal with weight loss (~9%) and result of thermal decomposition and loss of volatiles as well as char gasification (hydrocarbon of low molecular weight up to C6).

Figure (1b) shows the TG profile of waste tyre. It was found that tyre shows typical TG profile of waste tyre with maximum weight loss (~70%). Figure (1c) shows the TG profile of 1% tyre blended with coal. It shows typical TG profile with maximum weight loss (~8.5 %). Figure (1d) shows the TG profile of 3% tyre blended with coal. It was found that typical TG profile with maximum weight loss (~9%). Figure (1e) shows the TG profile of 6% tyre blended with coal. TG analysis curve showed weight loss was (~11%).

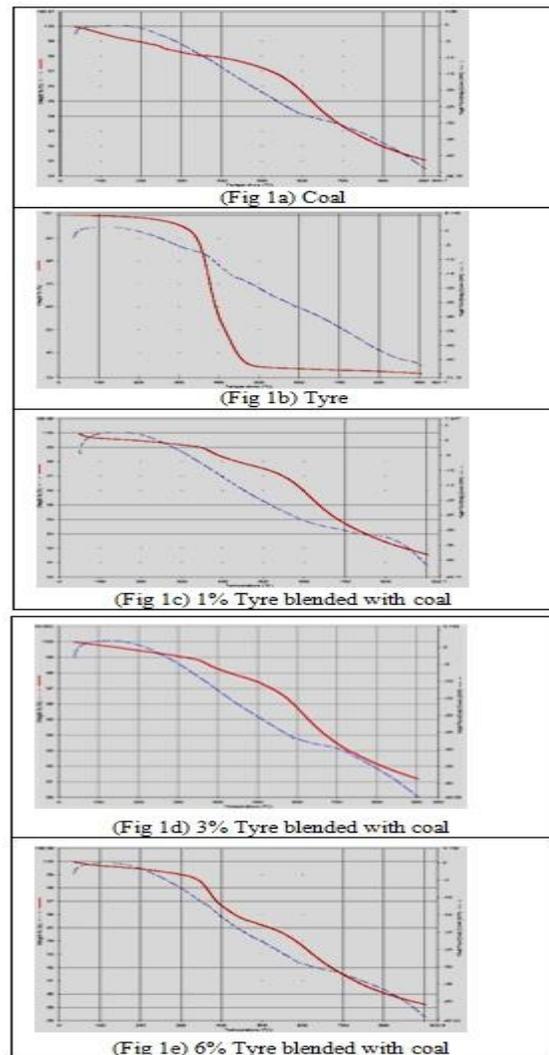


Figure 1 Thermo gravimetric Analysis (TG) of Coal, Tyre and Tyre blended with coal

Figure 2 shows Derived Thermo gravimetric Analysis (DTG) of Coal, Tyre, and Tyre blended with coal. Figure (2a) shows the DTG analysis of coal. Two distinct peaks were obtained at 250°C and 630°C respectively which may be attributed due to volatile product elimination. Figure (2b) shows the DTG analysis of tyre of two stages. The first peak is at 377.87°C due to the thermal decomposition of the mixture of oils, moisture, plasticizers and other additives. The second peak at 417.87°C may be attributed due to the thermal decomposition of natural rubber, polybutadiene and polybutadiene – styrene, the main constituents of tyres. Figure (2c) shows the DTG analysis of 1% tyre blended with coal.

The weight loss observed at two temperatures 380°C and 620°C respectively. Waste tyre at 380°C showed weight loss (~ 4.8%), where as the pure tyre showed (~ 70%) weight loss and the remaining (~ 30%) was steel. The second peak at 620°C is due to combustion of coal and (~ 8.5%) weight loss occurred. The weight loss of coal was (~ 7 %) in comparison with the result obtained in the blend (~ 8.5%). The disappearance of the peak at 250°C occurred in case of 1% blend sample. Figure (2d) shows the DTG analysis of 3% tyre blended with coal. There are two broad peaks appeared at 380°C and 620°C respectively. However, the nature of the peaks is broader in comparison with 1% blending. The weight loss was (~ 3.3 %) at 380°C and (~ 4.5%) at 620°C respectively. The disappearance of the peak at 250°C also observed in case of 3% blended sample. Figure (2e) shows the DTG analysis of 6% tyre blended with coal. There are two broad peaks. The peak appeared at 380°C showed (~ 11.2%) weight loss and the second peak at 620°C showed (~ 7%) weight loss.

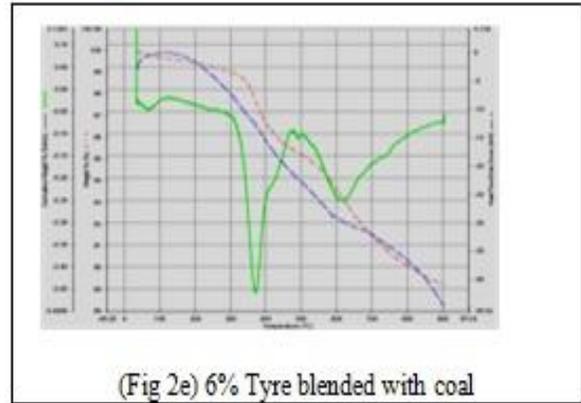
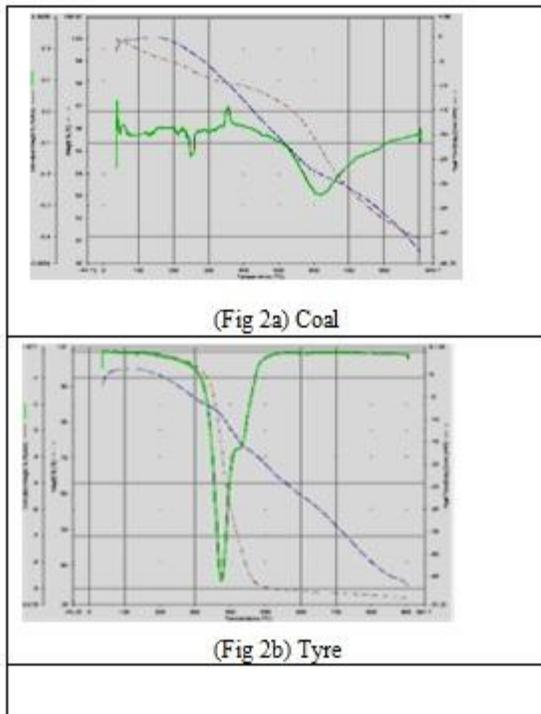
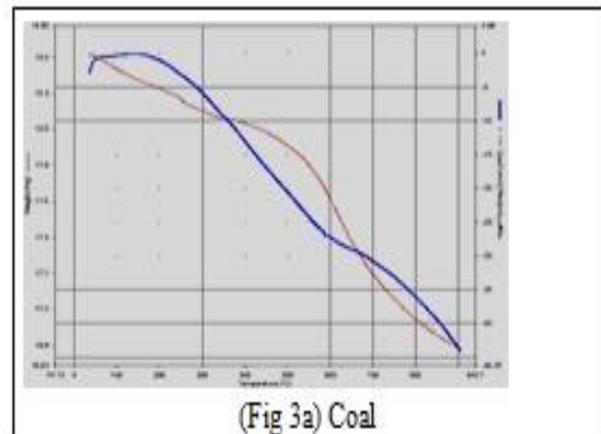
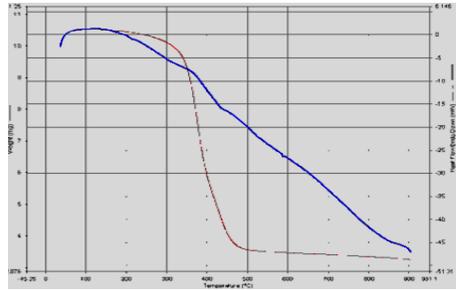


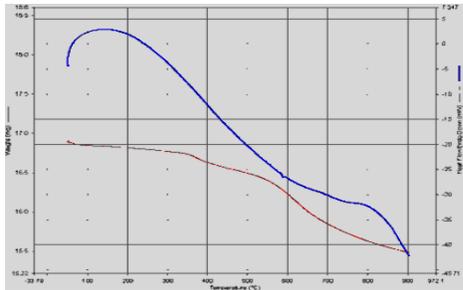
Figure 2 Derived Thermo gravimetric Analysis (DTG) of Coal, Tyre and Tyre blended with coal.

Figure 3 shows Differential Thermal Analysis (DTA) of Coal, Tyre and tyre blended with coal. Figure (3a) shows the DTA analysis of coal. The area under the DTA peak may be related to the heat produced in combustion process that is the high calorific value (HCV). This was the consequence of a greater process of volatile matter in the coal at 250°C and 630°C. Figure (3b) shows the DTA analysis of the waste tyre. The result derived from DTA analysis also showed two peaks at 377.87°C and 417.87°C respectively. Figure (3c) shows the DTA analysis of 1% tyre blended with coal. The result derived from DTA analysis also showed two peaks at 380°C and 620°C respectively. Figure (3d) shows the DTA analysis of 3% tyre blended with coal. The result derived from DTA analysis also showed two peaks at 380°C and 620°C respectively. Figure (3e) shows the DTA analysis of 6% tyre blended with coal. The result derived from DTA analysis also showed two peaks at 380°C and 620°C respectively. The low boiling point organic compounds present in the coal can mix with waste tyre and decomposes at 380°C which is a broader range from 300°C to 400°C.

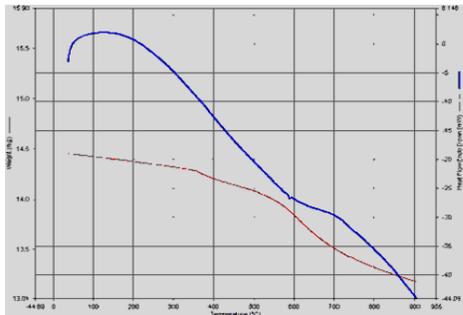




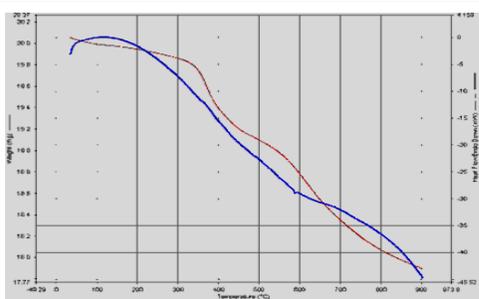
(Fig 3b) Tyre



(Fig 3c) 1% Tyre blended with coal



(Fig 3d) 3% Tyre blended with coal



(Fig 3e) 6% Tyre blended with coal

Figure 3 Differential Thermal Analysis (DTA) of Coal, Tyre and Tyre blended with coal.

For blends of waste tyre and coal, no interactions between blend components are observed in TGs. However, DTGs indicated that a comparatively important difference can be seen that may be related to a certain degree of interaction between the components. The co-combustion of waste tyre and coal cannot be predicted from the weighted sum of the blend components. The incorporation of waste tyre can

improve the combustion efficiency of coal, especially the ignition and the peak weight loss compared with the separate burning of waste tyre and coal, which indicate that the combustion of waste tyre and coal as alternative fuel is feasible in industry.

IV. COMBUSTION BEHAVIOR

The combustion characteristics of pulverized coal have been extensively studied, but little has been reported on the combustion of waste tyres. A comparison on the combustion characteristics of single particles (80-200µm) of both fuels was recently conducted in this laboratory, under high heating rates (10⁵ °C/s). In this study, separate volatile and char combustion phases were detected for the coal particles examined. Tyre particles experienced an intense primary volatile combustion phase, followed by a phase of secondary evolution and burning of volatiles, of lesser intensity, and simultaneous char combustion. During the initial volatile phase combustion, the peak flame temperatures were comparable for both materials and were in the range of 2200-2400 K at a gas temperature of 1150°C (1423K). The secondary volatile/char combustion phase observed for the tyre particles was cooler i.e.1423K. The coal chars burned even cooler, with surface temperatures of 1850-2000K. Combustion was found to be diffusion ally controlled. Char burnout time were much shorter for tyre particles than for coal particles of the same size, which can be attributed to the secondary devolatilization and the lower density of the former.

COMBUSTION EMISSIONS-The most important emissions from the combustion of coal and tyres are the inorganic gases sulphur dioxide(SO₂) and nitrogen oxide (NO_x), submicron metal aerosols (fumes), and toxic organic emissions, such as polynuclear aromatic hydrocarbons (PAHs), soot, and carbon monoxide(CO). Of recent concern are also the emissions of carbon dioxide (CO₂).

The present study was undertaken to assess and compare PAH emissions and CO₂ emissions from pulverized coal and waste wire-in-tyre crumb burning under well-controlled conditions. The compositions of fuels were tabulated in Table 1.

Table.1Composition of Fuels

Property	Ground tyre (SBR)	Coal
Particle size (µm)	180-212	63-75
Fixed carbon (%)	21.7	51.9
Volatiles (%)	52.3	34.4
Ash (%)	26.0	13.7
Carbon (%)	60.9	71.9
Hydrogen (%)	5.3	4.7
Sulfur (%)	2.46	1.36
Nitrogen (%)	0.28	1.36
Oxygen (%)	7.1	7.0
Heating value(MJ / kg)	29	29.2

The goal was to understand the influence of combustion parameters on toxic emissions. Combustion of clouds of particles (aerosols) of pulverized coal and tyres under steady-state/steady-flow conditions took place in Nelson reactor, in air, at a gas temperature of 1150°C. Emissions were monitored at various fuel mass flow rates that resulted in overall bulk equivalence ratios that differed widely. Experiments were also conducted under pyrolytic conditions (in an inert gas atmosphere i.e. argon) to simulate a worse-case scenario in a pulverized-fuel furnace, i.e. severe oxygen deficiency.

Polynuclear aromatic hydrocarbons (PAHs) were monitored at the exit of the furnace by trapping the particulate (condensed) and gas-phase compounds separately. The sampling stage was placed directly below the furnace to minimize losses. The products were characterized using GC/MS techniques. The further work is under progress.

V. CONCLUSION

Coal and waste tyre at various compositions were burnt in a Nelson Reactor in presence of N₂ gas as well O₂ gas. The amount of PAH generation were reduced in presence of O₂ gas in comparison with N₂ gas. For coal, a few of the PAHs, such as fluoranthene, pyrene and cyclopental pyrene showed an increase in concentration (by a factor 2) when oxygen was introduced, however most PAHs decreased and the total amount were 7.58 mg/(g of coal) in N₂ and 6.39 mg/(g of coal) in the presence of O₂. The combustion is predominantly dependent on sample size and mixing with gases for tyre, but much less so for coal. The total PAH emissions were 1.82 mg/g for tyre and 0.72 mg/g for coal.

When additional oxygen was introduced, the PAH emissions diminished. For coal, PAH emissions were rarely detected except of naphthalene. For tyre crumb, PAHs could not be detected. The major component CO₂ was thought to be reused in the Cement Industry. The small amount of mutagenic components should be adsorbed using polymeric hydrophobic nanofiber. The work is currently under progress. From the above study it is highlighted that combustion of waste tyre along with coal can be used as environmentally safe fuel in Cement Industry in future.

REFERENCES

- [1] Schumacher K. and Sathaye J., "Indian's Pulp & Paper Industry; Productivity & Energy Efficiency." J of Economic research, Vol. 4, 2001, pp. 1-46.
- [2] Banerjee R and Khurana S., "Energy Balance and Cogeneration for a Cement Plant." J. of Applied Thermal Engineering, Vol. 22, 2002, pp. 485-494.
- [3] Hendriks C., Worrell E., "Emission Reduction of Greenhouse Gases from the Cement Industry." "Greenhouse Gas R&D"
 - a. Programme IEA, www.ieagreen.org.uk/prghgt 42. htm, 2004
- [4] Amit G. and Shukla P., "Emissions Inventory of India", Tata McGraw-Hill Publishing Company Ltd, New Delhi, 2002.
- [5] Worrell E., "Potentials for energy efficiency improvement in the US cement industry." J. of Energy, Vol. 25, 1999, pp. 1189-1214.
- [6] Asthana, S.R. and Patil, R.K., "Use of Alternative Fuels in Indian Cement Industry." Proceeding of National Conference on Advances in energy research, Indian Institute of Technology, Bombay, 2006.
- [7] Mokrzycki E., Uliasz-Bochericz A. "Alternative fuels for the cement industry." J. of Applied Energy, Vol. 74, 2003, pp. 95-100.
- [8] Kaantee U., Zevenhoven R., Backman R., Hupa M., "Cement Manufacturing Using Alternative Fuels and Advantages of Process Modelling." J. of Fuel Process Technology Vol. 85, 2004, pp. 293-301.
- [9] John Kemm., Andrew C., "Health impact assessment of proposal to burn tyres in a cement plant." J. of Environmental Impact Assessment Review, Vol. 24, 2004, pp. 207-216.
- [10] Flagan, R. C.; Seinfeld, J. H. "Fundamentals of Air Pollution Engineering"; Prentice Hall: Englewood Cliffs, NJ, 1988.
- [11] Leung, D. Y. C.; Lam, G. C. K. Presented at the 3rd Asian-Pacific International Conference on Coal and Energy Utilization, 1995.
- [12] Leventis, Y. A.; Atal, A.; Steciak, J. Presented at the Twentieth International Conference on Coal Utilization and Fuel Systems, Clearwater, FL, Mar 1995.