Gasification of Nigerian bituminous coal in shallow bed

J Soji Adeyinka\* & F O Akinbode\*

\*Chemical Engineering Department, University of Port Harcourt, Port Harcourt, Nigeria
\*Mechanical Engineering Department, Federal University of Technology, Minna Nigeria

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Gasification experiment was carried out on Lafia Obi Bituminous (LOB) coal grades of Nigeria. Adiabatic carbon boundary condition was investigated using reduce coal-air feed ratio to evaluate coal conversion. CO:CO₂ gas yield followed coal property with increasing CO production at lower air-feed ratio; it was also observed that air distribution into the freeboard improved conversion and CO yield reducing CO₂ production. Thermal analysis of the gasification showed possibility of using excess heat from the hot bed zone to convert CO₂ in the freeboard.

Increasingly high cost of energy especially electrical and fossil fuel and the ultimate prospect of energy shortage have led to much attention being given to coal usage worldwide. Coal has a primary advantage of unique effective usage without any waste that could otherwise pose a disposal or localised pollution problem; also, emission from coal are marginally cleaner than those from hydrocarbon fuel with respect to formaldehyde pollution. Absence of lead as additives and reduced sulphur emission are advantages of coal usage. Little has been reported on the technology of Nigerian coal usage.\textsuperscript{1-3} The relationship between gasification rate and the bed porosity depends on flow conditions. Fluidization presents a typical problem of non-linearity in operational conditions (especially heat and mass transfer) this will require developing a definitive gasification condition that will suit Nigerian coals.

Table 1 shows the parameters of Nigerian coal as used in this experiment. From the Table Lafia Obi Bituminous (LOB) coal can be gasified with some modification. Based on these, LOB gasification stands the trial of malfunctioning; thus it is required to solve the problem of optimal design for gasifier reactor for Nigerian coal. This is because different coal grades will perform differently under a given condition.\textsuperscript{4-6}

The ratio of air fed and the volatile contribute to the overall gasification’s gas composition, provision must be made for a general assessment of both air feed composition and the percentage of the volatile. If the coal contains a high proportion of volatile matter this will escape from the bed as un-burnt gases. If such volatile matters should react in the bed this may lead to increase bed temperature and variation in exit gas composition during gasification process.\textsuperscript{7} Subsequent to their evolution, if the volatile gases are heated to temperature above 900°C in a region of local oxygen deficiency, part of the carbon content of the hydrocarbon is converted to soot. Deposition of such soot in the bed may lead to reduce effectiveness of the gasification process.\textsuperscript{8} Incomplete combustion on the other hand will increase the carbon dioxide content of the gasification product, this will also reduce thermal efficiency.\textsuperscript{9} This study considers gasification of Nigerian coal grades to evaluate possible implementation of research findings, ascertain the most appropriate and optimal condition for Nigerian bituminous coal grade.

Experimental Procedure

The ultimate analysis of three types of coals used is shown in Table 1. Coal preparation and gasification procedure had been reported earlier.\textsuperscript{2-9} After establishing gasification conditions, batch-experiment was carried out using standard procedure of feeding the coal into the reactor through a funnel with a fluidizing velocity as earlier reported elsewhere.\textsuperscript{2,10} The following parameters were fixed for the bed:

- Coal particle size: 15-25 mm
- Inert particle size: 15 mm
- Dolomite sand: 2500 g
- Seashell catalyst: 55 g
- Bed temperature: 850°C
- Static bed depth: 0.6 m

\*For correspondence
The air feed was regulated by the flow-meter and sent in through the distributor air inlet. The calculated air was then supplied into the bed (at the air feed rate of 3401/m). After satisfying these conditions, the reactor was fed continuously with coal (3 kg) was fully loaded into the bed, and both the evolved volatile and air feed ratio to the particulate region where for conversion of CO₂ and carbon into CO was 340 l/m). After satisfying these conditions, the reactor then supplied into the bed, and both the evolved volatile and air feed ratio to the particulate region where for conversion of CO₂ and carbon into CO was 340 l/m). After satisfying these conditions, the reactor then supplied into the bed, and both the evolved volatile and air feed ratio to the particulate region where for conversion of CO₂ and carbon into CO was 340 l/m). 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constant gas formation in LOB and LOB unwashed, the LOB washed showed a sharp downward trend in gaseous product yield up to 0.95 and remained constant up till 1.0 air-factor. The wide deviation between the gaseous products 80% at the upper extreme (LOB washed) and 50% at the lower extreme (LOB unwashed) under equal operational condition (Fig. 1) can be attributed to the chemical properties of the coals used, its origin and the pre-treatment condition of the washed sample. During gasification, reduction in air factor increased CO formation thereby reducing CO₂ concentration in the gas product (Fig. 1). Fig. 2 shows the effect of excess air on coal conversion.

From Fig. 2, it was found that there was a falling in gas quality with respect to carbon (II) oxide. This was as a result of increased carbon dioxide concentration. Above 88% (8.88) stoichiometric oxygen demand, lead to a fall in CO formation thereby increasing CO₂ formation in the gasifier, although this followed a similar trend for all the coal grades, LOB unwashed showed the highest CO₂ formation while LOB washed showed the least with a CO formation of 33% and 27.5% respectively. From Fig. 2, an increment of 1% of air-feed (92%) showed downward trend of 2% for LOB unwashed and 28% for LOB washed for CO formation. These will correspond to a 12% increase in CO₂ for LOB unwashed and 9% increased in CO₂ for LOB washed. This report conformed to an earlier report. At the same condition, LOB had 10% increase in CO₂ formation. It is important to note that at 100% stoichiometric oxygen demand both LOB and LOB washed showed practically equal CO and CO₂ formation while LOB unwashed showed the least CO yield with nearly 5% conversion of CO to CO₂ which was maintained up to 110% air-feed. Beyond 100% air-feed LOB maintained constant CO concentration but LOB washed showed an improved CO formation of about 1.5% to every 1% increase in air-feed above stoichiometric air feed. This can be attributed to the fact that LOB washed is a beneficiated sample with higher carbon content ratio when compared to the other samples (LOB and LOB unwashed).

It was observed that at constant temperature, heat released in the freeboard depended mainly on the concentration of the available volatile and free air that affected the reaction of C to CO. Evidence of increased CO concentration observed showed improved efficiency of coal usage.

Conclusions
From the gasification product analysis, air-feed and coal quality affected coal gasification positively in this experiment. It was observed that at low air-coal feed ratio, devolatilization of hydrocarbons was observed in the freeboard. This affected the exit gas composition with increased CO. Also, freeboard temperature above 500°C was found useful in this experiment, this is an indication that in-bed cooling may not be very necessary to effect constant freeboard temperature.

References