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THE EFFECT OF COAL QUALITY ON NITROGEN OXIDES FORMATION DURING PULVERIZED COAL COMBUSTION

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INTRODUCTION

One of the issues of coal use in Japan is to reduce nitrogen oxides emission. Though a lot of efforts are focussed on developing not only technologies to minimize nitrogen oxides generation during combustion ,but also those to convert nitrogen oxides in flue gas to molecular nitrogen using catalytic reaction with NH_3 gas, use of coals which form less nitrogen oxides is another important approach to reduce nitrogen emission.

In general, it is believed that nitrogen oxides emission during coal combustion is mostly based on fuel nitrogen and the higher nitrogen content coal generates the more nitrogen oxides. Practical experimental results show that most nitrogen oxides are generated from coal nitrogen, however there is no direct relation -ship between coal nitrogen content and nitrogen oxides formed.

Investigations of the effect of coal quality on nitrogen oxides formation were performed with a turbulent flow furnace. Correlation study between coal nitrogen conversion rate to nitrogen oxides and various kind of components of coal properties was closely developed and new index (NOx Index) to predict conversion(%) of coal nitrogen to nitrogen oxides for different kinds of coal at a constant carbon burnout was found.

The mechanism of nitrogen oxides formation and reduction by air staged combustion was discussed in this study.

EXPERIMENTAL

This investigation was carried out with a 30cm diameter and 2.8m long vertical type turbulent flow furnace. The feed rate of pulverized coal was about 5kg/hr. Larger size of particles than 100 mesh were removed from feed pulverized coal to obtain comparable carbon conversion results to those of commercial boilers. Gas and solid samples were collected with water cooled probe through 17 sampling ports which were installed every 15cm on the furnace side wall. Composition of flue gas was analyzed by in-situ process analyzers such as chemiluminescent(NO), paramagnetic(O_2) and NDIR(CO,CO_2,CH_4,SO_2).

Overall excess oxgien after combustion was controlled at 4%

level(dry base). Staged air combustion was applied to reduce nitrogen oxides, and fuel/air stoichiometric ratio for first stage was varied from 0.7 to 1.2.

Flash pyrolyzer(CHEMICAL DATA SYSTEM INC.Model 120) was used to study the behavior of volatile nitrogen compounds during rapid heating. Heating rate of the pyroprobe system was 4.8×10^4 °K/min and final temperature reached to 1673 °K.

Coals and chars were determined by usual analysis, proximate and ultimate analysis.

RESULTS AND DISCUSSION

To investigate correlation between coal quality and nitrogen oxides formation, nitrogen content of various coals and nitrogen oxides emitted from the coals after combustion were plotted in Fig. 1. There is no good relationship between nitrogen content of coal and nitrogen oxides emitted from the coal, though it is believed in general that nitrogen oxides emission during coal combustion is mostly based on fuel nitrogen and the higher nitrogen content coal forms the more nitrogen oxides. New Index to predict nitrogen oxides formation from coal is required.

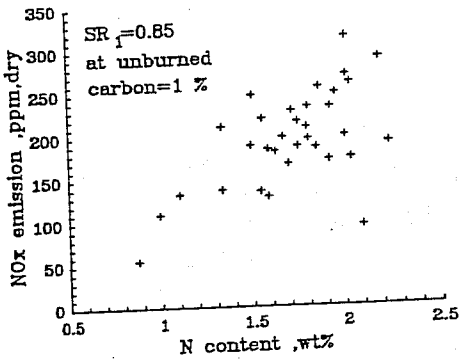

Fig 1. Correlation of coal nitrogen content(daf) and NOx emission(6%O_2).

Fig. 2 shows profiles of nitrogen oxides concentration for various coal during combustion process in the vertical type turbulent flow furnace. Staged air was injected at the position of 95 cm from the burner. Nitrogen oxides increase very rapidly right after the burner, and reach to the maximun point at the middle between the burner and staged air injection point, followed by gradual decreasing.

In the initial stage of coal combustion, devolatilization occurs by rapid heating. Volitiles from pyrolized coal are ignited and flame temperature reaches to the maximum. A large fraction of fuel nitrogen is released as the volatiles by rapid heating in the initial stage of coal combustion. Released nitrogen compounds are partly oxidized and converted to nitrogen oxides and other nitrogen compounds, followed by reaction with hydrocarbon radicals and reduction of nitrogen oxides to molecular nitrogen. Staged combustion promotes formation of the hydrocarbon radicals and reduction of nitrogen

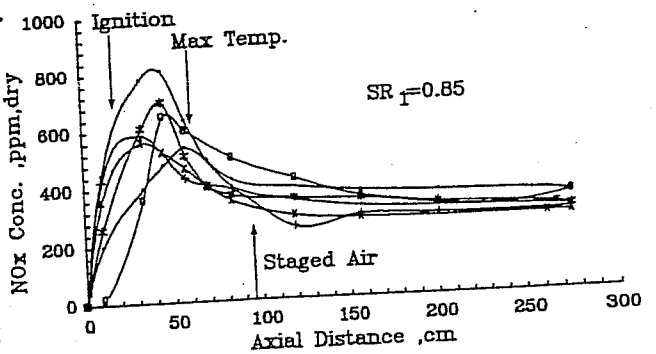

Fig 2. Profiles of nitrogen oxide at the centerline in the furnace.

oxides. The amount of coal nitrogen released from coal particles depends on the amount of volatiles by rapid heating and also types of nitrogen bound in the coal structures.

As seen in Fig. 2, there is a trend that the coals which have the higher maximum point of nitrogen oxides concentration give the more reduction of nitrogen oxides by air staged combustion.

Fig. 3 shows fractions of released fuel nitrogen as volatiles during combustion process for various coals. Rapid release of nitrogen compounds is seen in the initial stage. 80% of nitrogen is already released before reaching to the maximum flame temperature.

Fig. 4 shows the fraction of released nitrogen as volatiles at the point where nitrogen oxides concentration reaches to the maximum. 50% of fuel nitrogen is released before reaching to the maximum nitrogen oxides concentration for all coals tested.

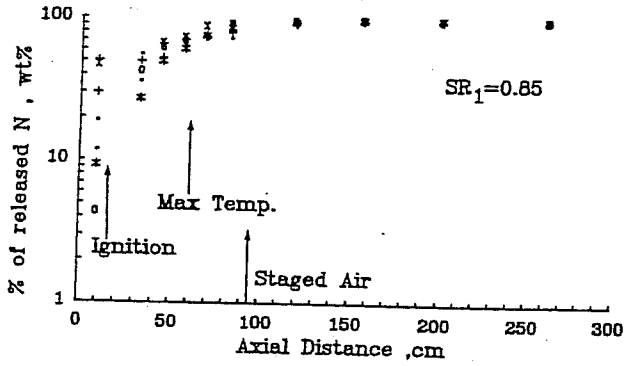

Fig 3. Profiles of released nitrogen at the centerline in the furnace.

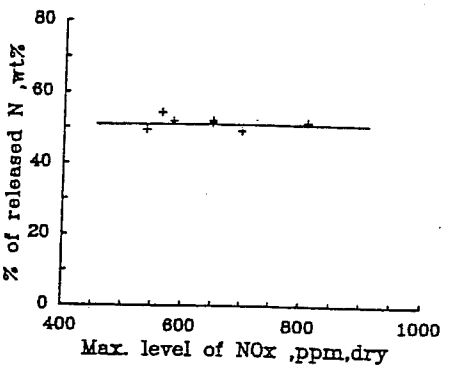

Fig 4. The fraction of released N at the maximum NOx level.

Nitrogen release from coal as volatiles under pyrolysis condition was studied by flash pyrolyzer heating rate of which was 4.8×10^4 °K/min. Fig.5 shows the relationship between the fraction of fuel nitrogen converted to nitrogen oxides during staged air combustion (NOx conversion) and the fraction of the released nitrogen from coal as volatiles under above pyrolysis condition. Though there are some scattered data, the lower nitrogen conversion is obtained for the coals which release the more fuel nitrogen during pyrolysis. According to the above results, the following assumption can be made;

Fuel nitrogen is released from coal as volatiles by pyrolysis right after injection from the burner, and is converted to nitrogen oxides, reacting with oxygen in combustion air. As released volatiles from coal are burned rapidly, most of oxygen in combustion air is consumed and formed nitrogen

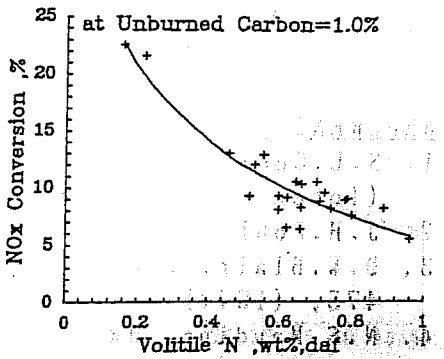

Fig. 5 Relationship between volatile N and NOx conversion.

oxides are converted to molecular nitrogen, reacted with hydrocarbon radicals after 50% of fuel nitrogen is released. The higher volatiles or nitrogen compounds release rate is obtained, the more residence time of reduction reaction of formed nitrogen oxides is maintained and the lower NOx conversion will be performed.

Fig.6 shows relationship between fuel nitrogen release rate and NOx conversion. There is a good agreement with the assumption.

New Index which is calculated from usual coal analysis, such as proximate and ultimate analysis, gives a good relationship with fuel nitrogen release rate and can be used to predict NOx conversion as show in Fig.7.

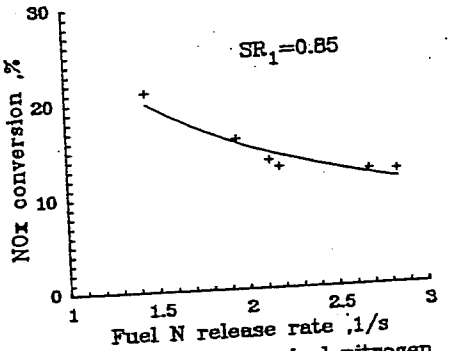

Fig. 6 Relationship between fuel nitrogen nitrogen release rate and NOx conversion.

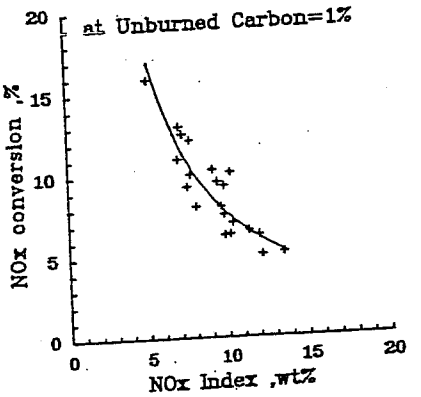

Fig. 7 Correlation of NOx Index and NOx Conversion.

CONCLUSIONS

(1) Nitrogen content of coal is not a good index to predict nitrogen oxides formation in combustion.

(2) Fuel nitrogen release rate is very high and more than 80% of fuel nitrogen is released before reaching to the maximum flame temperature.

(3) Nitrogen oxides concentraction shows the maximum at the point where 50% of fuel nitrogen is released under staged air combustion condition.

(4) New Index, NOx Index, to predict nitrogen oxides formation is found.

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