Estimation of NO_x Emissions

Summary

Pohl's Method

1. Heat Release Burner Zone Area (HRBZA)
   a. The NO_x correction factor (HR) for heat release in the burner zone area was based on plant data with no Low NO_x Burners, therefore the absolute value for the estimate for NO_x will be significantly higher than actual when LNB's are used.
   b. Some data for 2 stations (Muja and Earring) where the first over-fired air ports are level to a burner row on the opposite wall of the boiler were examined. No method was found that allowed the HRBZA to be adjusted to account for this firing arrangement and match performance data at different loads with NO_x emissions.
2. Plant data
   a. The required plant data is not readily available to determine HRBZA, CoalTech has reviewed over 10 plant performance reports carried out on various coals at different stations and none of those reports had sufficient data to calculated HRBZA. This data is not available in the IEA Coal Power station database and only limited data is available in other commercially available databases on power plants that are known to the author.
3. Staged or Unstaged Correlations
   a. In all calculations using Pohl's method the impact of coal properties (VM and N) was determined using the staged correlations. Unstaged correlations correctly indicate increasing NO_x emissions with increasing volatiles, for Low NO_x Burners (staged combustion) NO_x decreases with volatiles.
4. High temperature volatile yield
   a. The substitution of VM_{daf} with VM_{HT} did not improve the fit to plant data.

Makino's method

1. High temperature volatile yield
   a. The substitution of VM_{daf} with VM_{HT} did improve the fit to plant data.

The Makino's equation is easier to use as it does not depend on the availability of plant design data, requiring only the NO_x emissions of two coals to be known. For this data set, this method of predicting NO_x emissions seems to be more accurate of the two methods. Note when this method and the Danish data is used for NO_x prediction some coals in CoalTech's database give unrealistic high values.

Introduction

This section evaluates the correlations developed by Pohl and co-workers[1 2] and Makino[3] in the evaluation of NO_x emissions from power plant.
The influence of coal properties on NO_x emissions has been discussed in detail a previous report[4].

Pohl's Correlation

The relationships used by Pohl have been detailed in a previous report and were shown to give a reasonable estimate of the impact of coal properties on NO_x emissions especially when the emissions of a known coal are used to adjust the model to the performance of the power plant.

Makino Equation

Makino developed an equation that allows the fitting of NOx performance data of a boiler to the properties (fuel ratio -FR and nitrogen N_{dry})of the coals fired. As there are only 2 parameters (a_1 &a_2) used in the fitting of boiler data it is possible, if the performance of two coals are known for a given power station, to determine the NO_x emissions of other coals in that boiler. The Makino Equation is:

$$CR = a_1 \times \frac{FR}{N_{dry}} + a_2$$

where CR: Conversion ratio of fuel nitrogen to $_{Nox}$.

Plant Data

Gathering plant design data and NO_x emissions for a range of coals in those power plants proved to be difficult. The data supplied by the CRC to CoalTech on five power stations was insufficient to calculated the HRBZA and plant design data was sourced from other sources for three stations in Queensland (Callide B, Tarong, and Stanwell). These stations are all similar in design except Stanwell has a greater furnace height and depth giving a greater volume for the complete burnout of medium volatile coals. Additional data from the NO_x performance of 3 coals (Columbian, Polish and South African) in 2 different Danish power stations[5] (Funen and Midtkraft) was also used.

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[1] **Pohl J.H., Dusatko G.C., Orban P.C., and Mcgraw R.W., 1987**, *"The influence of fuel properties and boiler design and operation on NO_x Emissions"*, Joint Symposium on Stationary Combustion NO_x Control, EPRI, New Orleans, March 1987.

[2] **Alfonso R., Dusatko G.C., Pohl J.H., 1991,** *"Prediction of NO_x emissions from coal boilers"*, First International Conf. Combustion Technolgies for a Clean Environment, Portugal, September, 1991

[3] **Makino K., 1999,** *"The use of Australian coals as pulverized coal in Japan"*, CRC for Black Coal Utilisation Seminar, The Future of Pulverized Coal Firing, Newcastle, March 1999.

[4] **Bennett P., 2000,** *" NO_x predictions"*, CoalTech Report to ACARP Project C7053, May 2000.

[5] **van der Lans, R. P., Glarborg P., Dam-Johansen K., Knudsen P., Hesselmann G., Hepburn P., 1998**, *"Influence of coal quality on combustion performance",* Fuel, Vol .77, No. 12, 1998.

Funen power station is a 400MW$_e$ corner fired unit and the Midtkraft is a 350 MW$_e$ opposed fired unit.

Using Pohl's Method

NO_x emissions estimated (Pohl) from a reference coal in similar design station.

The NO_x emission of Curragh coal at Stanwell was used as the reference point to determine the NO_x emissions from Callide and Tarong stations firing Dunn Creek and Meandu coals respectively.

Coal / Power Station	Actual NO_x (6% O_2)	Estimated using Pohl's method NO_x (6% O_2)	Estimate corrected to match Curragh performance at Stanwell NO_x (6% O_2)
Curragh/Stanwell	720	564	-
Meandu/Tarong	728	547	700
Dunn Creek/Callide	637	634	813

The estimated NO_x emissions for Tarong, when corrected to the reference coal, was very good. The corrected estimate for Callide was considerably higher than the actual NO_x emissions. This may indicate that better NO_x control strategies are being used at Callide .

NO_x emissions estimated (Pohl) from a reference coal in same station

Using the data of van der Lans for the Midtkraft Studstrup Power Station with Pohl's method to estimate NO_x and the Columbian coal as the reference coal.

Coal	Actual Midtkraft Studstrup Power Station NO_x (6% O_2)	Estimated using Pohl's method NO_x (6% O_2)	Estimate corrected to match Columbian coal's performance at Midtkraft NO_x (6% O_2)
Columbian VM daf = 39.9 N daf = 1.94	296	707	-
Polish VM daf = 35.9 N daf = 1.59	262	665	278
South African VM daf = 28.7 N daf = 2.12	420	834	349

NO_x emissions estimated (Pohl) from a reference coal in different station

Using the data of van der Lans for the Midtkraft Studstrup Power Station with Pohl's method to estimate NO_x and the Columbian coal as the reference coal to predict the performance of the three coals in the Funen Power station. Note the reference station (Midkraft) is a opposed fired unit while the Funen unit is a corner fired unit so the fit to actual data was not expected to be good.

Coal	Actual Funen Power station NO_x (6% O_2)	Estimated using Pohl's method NO_x (6% O_2)	Estimate corrected to match Columbian coal's performance at Midtkraft NO_x (6% O_2)
Columbian VM daf = 39.9 N daf = 1.94	248	707	201
Polish VM daf = 35.9 N daf = 1.59	220	665	189
South African VM daf = 28.7 N daf = 2.12	330	834	237

Using Makino Equation

The NO_x data for the Columbian and Polish coals in the two stations (Funen and Midtkraft) was used to predict the NO_x emissions of the South African coal in these stations.
These calculations were done using the fuel ratio (FR) calculated from the volatile matter daf and for when the FR was calculated from the high temperature volatile yield (VM_{HT}) as determined by the method of Badzioch[6]. These calculated VM_{HT} were similar to the yields from heated wire tests reported by van der Lans, except for the Columbian coal where the calculated result was 65% compared to the experiment result of 51.9%.

NO_x (6% O_2) Emissions for South African Coal			
Station	**Actual**	**Estimate using $VM = VM_{daf}$**	**Estimate using $VM = VM_{HT}$**
Funen	330	288	322
Midtkraft	420	344	384

The NO_x data for Tarong and Stanwell power stations as the reference to estimate the NO_x at Callide B. Note Stanwell design does different in terms of boiler height and width to those of Stanwell and Callide B, also the burner design are slightly different.

NO_x (6% O_2) Emissions for Callide B			
Station	**Actual**	**Estimate using $VM = VM_{daf}$**	**Estimate using $VM = VM_{HT}$**
Callide B	637	819	746

6 **Badzioch S., Hawksley P.G.W., 1970,** *"Kinetics of thermal decomposition of pulverized coal particles",* Ind. Eng. Chem. Process Des. Develop., Vol. 9, No. 4, 1970.