International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 6, Issue 8, pp 31-35, August-2022

https://doi.org/10.47001/IRJIET/2022.608005

Net Plant Heat Rate (NPHR) Analysis of Main Plant Boiler Unit (UIK) Towards Coal Additive Corint PC 99 Injection

[1]*Muchammad, [2]Yosef G P Napitu, [3]Budi Setiyana

[1,2,3]Mechanical Engineering Department, Faculty of Engineering, Diponegoro University, Jl. Prof. H. Soedarto, SH, Tembalang-Semarang 50275, Indonesia

*Corresponding Author Email: muchammad5373@gmail.com

Abstract - **Steam power plant (SPP) is the most popular power plant and the largest power generator in Indonesia. SPP uses coal as fuel to produce heat energy. The coal that is taken and used by the SPP must be in accordance with the boiler specifications. However, at the end of 2021, Indonesia experienced a coal shortage crisis, forcing SPP to use a lower coal calorific value specification than usual. Therefore, there is a slagging phenomenon in the wall tube which makes the reliability value of the generator worse. The reliability performance of a power plant can be determined from the calculation of the Net Plant Heat Rate (NPHR). NPHR is a value that represents the amount of energy used to produce electrical energy by a generator. The greater the NPHR value indicates that the boiler efficiency worsen. This is because it used more amount of energy to make 1 kW than usual. To overcome the slagging phenomenon that increases the NPHR value, boiler maintenance companies did an injection of coal additive CORINT PC 99 in the combustion chamber and coal silo. Thus the AFT value of coal is getting higher and the slag will collapse from the wall tube. If this happens, it is expected that the heat transfer from the combustion chamber to the walltube will be better and the NPHR value will decreases. After calculation, the injection of coal additives made the NPHR value increase by 4.08% which indicates that the treatment had no significant impact. However, the success parameter of coal additive injection is not only from the NPHR value but also from the amount of slag that falls and the hardness of the fallen slag. According to these 2 parameters, the injection of coal additive has succeeded in collapsing the slag and softening the slag attached to the walltube therefore it is easier to be cleaned by soot blower.**

Keywords: Net Plant Heat Rate, Slagging, Coal Additive.

I. INTRODUCTION

SPP X has 4 generating units, each with a gross capacity of 4 x 710 MW and a net capacity of 4 x 660 MW. The amount of capacity it has makes SPP X an important state asset to meet the electricity needs for Indonesia, especially on the area such as Java, Bali or Madura. This coal-fired steam power plant is very favourable considering it is relatively cheap to produce a large amount of energy and Indonesia still has a lot of coal reserve. SPP X is also equipped with a coal jetty and ship unloader which was the supporting infrastructure for the power plant (Akbar, 2019).

SPP X uses a sub-critical boiler. Sub-critical boiler operating conditions are less than 22,1 MPa where water is separated from saturated steam in a steam drum (Zhou, S. and Turnbull, A., 2002). One of the problems faced in a coal-fired power plant is slagging phenomenon. Slagging is a phenomenon of sticking coal ash particles, both solid and fused, on the surface of the wall tube located in the high temperature combustion gas zone, as a result of the coal combustion process (Suarez-Ruiz, 2008). If the burned coal has a relatively low Ash Fusion Temperature (AFT), the ash attached will form a layer and over time it will accumulate. Ash fusion temperature analysis is an analysis whose results can describe the melting properties of coal ash by measuring and observing changes in the shape of the ash sample that has been moulded into a cone, during gradual heating (Handayani, R.H.E., 2019).

Each boiler has a slag cleaning mechanism on the wall tube, super heater, reheater and economizer pipes, namely soot blower. Soot blower is one of the components in the boiler used to reduce slag, because if the slag is not cleaned or removed then the slag can affect the heat of the boiler itself (Felani, A. and Al-Janan, D.H., 2021). However, if the slag is too hard, the soot blower will not be able to clean it away. Therefore, other solutions are needed to overcome this problem. To overcome this problem, coal additive injection is used. Coal additives are chemical compounds consisting of emulsifiers, dispersing agents, corrosion inhibitors and penetrants. Coal additives contain O, Mg, Al, Si, S, Ca, Ba and Mn. Coal additives work to achieve complete coal combustion and to reduce heat caused by chemical and

ISSN (online): 2581-3048
Volume 6, Issue 8, pp 31-35, August-2022
https://doi.org/10.47001/IRJIET/2022.608005

mechanical incomplete combustion of coal so that the use of coal can be saved (Lin Xiaojuan, 2011). Then, to analyze the success of coal additive injection on the boiler, Net Plant Heat Rate (NPHR) method was used. NPHR is an indicator of reliability and efficiency of a thermal power plant, especially a steam power plant. That way, the NPHR analysis can be used as a success parameter of coal additive injection in breaking down the crust on the wall tube.

II. RESEARCH OBJECT

2.1 Coal Additive Injection

Due to slagging problem in SPP X unit 4, efforts were made to minimize and overcome the presence of slagging in the boiler, namely magnesium additive injection, because of its ability to increase the AFT of minerals in coal. The magnesia-based additive is also able to improve the quality of combustion and is able to change the hard slag which has a fairly strong bonding strength in the pipe, into a soft crust (porous) so that it will be easily collapsed by soot blowing treatment (PT Regi Jaya, 2011). The coal additive used by the boiler maintenance company is CORINT PC 99 with an application dose of 1 kg per 15 tons of coal. The additive is a magnesia base combustion improver with a loss of drying of 0,4% and a light burn type. It is hoped that with the injection of coal additives, the following chemical reactions will occur which are expected to break down the slag/crust:

$$MgO + SO_2 \leftrightarrow MgSO_3$$

Magnesium oxide + Sulphurdioxide= magnesium Sulphite

Magnesium Sulphite has the character of porosity so that it easily peels off.

2.2 Slagging Potential

The slagging potential in the boiler will occur if the ash particles are on the surface of the heat absorber whose temperature is relatively greater than the softening temperature for a long time, then pyroplastic (liquid deposite) will be formed, coarse in shape, tightly bound and difficult to remove (PT Regi Jaya, 2011). The slagging potential can be determined from the percentage of ash content contained in the coal used, the following acid-base ratio equation is used to calculate the slagging potential:

$$R = \frac{B}{A} \quad (1)$$

$$R = \frac{Fe_2O_3 + CaO + MgO + Na_2O + K_2O}{SiO_2 + Al_2O_3 + TiO_2} \quad (2)$$

Description:

Acids (A): *Silicon dioxide* (SiO_2), *Aluminum oxide* (Al_2O_3), *Titanium dioxide* (TiO_2).

Base (B): *Iron oxide* (Fe_2O_3), *Calcium oxide* (CaO), *Magnesium oxide* (MgO), *Potasium oxide* (K_2O), *Sodium oxide* (Na_2O).

Table 1: Classification of Coal Slagging Potential

Value	Classification
<0,4	Low potential slagging
0,4<R<0,7	High potential slagging

2.3 Net Plant Heat Rate (NPHR)

NPHR is a value that represents the amount of energy used to produce 1 kW of electricity by a power plant. The greater the NPHR value indicates the inefficiency of boiler performance. This is due to the increasing amount of energy used by the power plant, yet the electrical energy that was produced by the power plant remains still or was getting smaller (Nainggolan, 2021). The more slag attached to the wall tube, the worse the heat transfer from the combustion zone to the wall tube can be, thereby reducing the efficiency of the unit. The NPHR value can be calculated with the following formula:

$$\text{NPHR: } \frac{\text{Amount of Coal x HHV Caloric Value}}{\text{Nett Output}} \quad (3)$$

Description:

Amount of Coal Used (kg)
HHV Caloric Value (kcal/kg)
Net Output (kwh)

2.4 Data Collection

The authors conducted a literature study and field study to analyze the effect of coal additive injection on boiler NPHR. There are several sets of data needed to calculate NPHR and slagging potential. The data will be calculated using the formula that has been obtained, and the final result can present whether coal additive injection makes the boiler more optimal as one of the success parameters for this study.

III. RESULTS AND DISCUSSION

3.1 Coal Additive Injection Process

The coal additive injection at SPP X unit 4 is carried out by two methods, namely:

1. Mixed directly with coal before entering the coal bunker or pouring the coal additive in the coal silo.

International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 6, Issue 8, pp 31-35, August-2022

https://doi.org/10.47001/IRJIET/2022.608005

2. Injection by blowing the coal additive into the furnace through manhole at the side of the boiler.

The injection of coal additive at SPP X unit 4 was carried out on January 4th, 2022 – January 16th, 2022. The injection was conducted four times per day starting at 08.00 WIB with a total daily average injection of 800 kg.

Table 2: Coal Additive Injection

Date	Additive Injection Furnace (kg)	Additive Injection Coal Bunker (kg)
03-Jan-22	0	0
04-Jan-22	500	0
05-Jan-22	500	300
06-Jan-22	150	650
07-Jan-22	400	400
08-Jan-22	0	800
09-Jan-22	0	800
10-Jan-22	0	800
11-Jan-22	0	800
12-Jan-22	400	400
13-Jan-22	400	400
14-Jan-22	400	400
15-Jan-22	400	400
16-Jan-22	400	400
Total	3.550	6.550

3.2 Slagging Potential Calculation

To calculate the slagging potential in coal used in SPP X, the authors conducted a literature study and found two types of coal used, namely Supplier A and Supplier B. Ash content of each coal is as follows:

Table 3: Coal Ash Content Analysis

Compound	Unit	Supplier A	Supplier B
SiO_2	%	47,42	45,61
Al_2O_3	%	19,18	21,08
Fe_2O_3	%	18,92	18,60
TiO_2	%	092	5,30
CaO_2	%	6,75	4,92
MgO	%	3,64	2,04
K_2O	%	0,30	0,56
Na_2O	%	0,23	0,24
P_2O_3	%	0,61	0,49
SO_3	%	1,26	095

Based on the characteristics of each coal supplier at SPP X in the table above, the acid-base ratio method can be used to determine the slagging potential occurred in the SPP X unit 4 boiler. The slagging potential calculation from ash content percentage is as follows:

1. Supplier A

$$R = \frac{Fe_2O_3 + CaO + MgO + Na_2O + K_2O}{SiO_2 + Al_2O_3 + TiO_2}$$

$$R = \frac{18{,}60 + 4{,}92 + 2{,}04 + 0{,}24 + 0{,}56}{45{,}61 + 21{,}08 + 5{,}3}$$

$$R = 0{,}5769$$

2. Supplier B

$$R = \frac{Fe_2O_3 + CaO + MgO + Na_2O + K_2O}{SiO_2 + Al_2O_3 + TiO_2}$$

$$R = \frac{18{,}92 + 6{,}75 + 3{,}64 + 0{,}23 + 0{,}3}{47{,}92 + 19{,}18 + 0{,}92}$$

$$R = 0{,}4387$$

If the value of R is in the range of 0,4 – 0,7, it indicates high slagging potential. Based on acid-base ratio calculation, the coal that was supplied for SPP X unit 4 from each company has a high potential slagging.

3.3 NPHR Analysis

3.3.1 NPHR Calculation

In calculating NPHR, some data is needed such as unit net power, coal calorific value (HHV), and the amount of coal used. The net power calculation is obtained by subtracting gross power from auxiliary power and multiplying by 24 hours of operating time in one day. The amount of coal can be calculated from the coal feeder total flow and multiplied by 24 hours of operating time in one day. So based on January 3rd 2022, the NPHR can be calculated as follows:

- Net power: Unit Gross Power–Auxiliary Power

: 668 MW – 31,3 MW = 636,7 MW

Net Power (24 hour) = 636,7 MW x 24

=15.280,8 MWH

Converted= 15.280.800 KWH

- Amount of Coal Used

  Coal feeder total flow= 259,1 ton/hour

  (1 day) = 259,1 ton/hour x 24 hr

  Total coal consumption = 6.227,2 ton

  Converted =6.227.200 kg

- Coal Caloric Value (HHV)=5.584 kcal/ kg

Then it can be calculated using the NPHR formula, that boiler NPHR on Monday, January 3rd2022 is:

ISSN (online): 2581-3048
Volume 6, Issue 8, pp 31-35, August-2022
https://doi.org/10.47001/IRJIET/2022.608005

$$NPHR = \frac{\text{Amount of Coal x HHV Caloric Value}}{\text{Net Output}}$$

$$= \frac{6.227.200 \text{ kg x } 5.584 \text{ kcal / kg}}{15.280.800 \text{ kwh}}$$

= 2.275,58 kcal/ kwh

So, on Monday, January 3rd 2022, the NPHR value of SPP X unit 4 is 2,275.58 kcal/kwh. If the calculation process is continued until the last injection day, the NPHR data will be obtained in the following table presented on table 4 until table 6.

Table 4: Generated Net Power Calculation

Date	Unit Gross Power	Auxiliary Power	Unit Net Power	
Unit	MW	MW	MW	kWH (24 hour)
03-Jan-22	668,0	31,3	636,7	15.280.800
04-Jan-22	680,0	32,2	647,8	15.547.200
05-Jan-22	682,0	32,3	649,7	15.592.800
06-Jan-22	683,0	32,8	650,2	15.604.800
07-Jan-22	666,0	32,3	633,7	15.208.800
08-Jan-22	681	33,6	647,4	15.537.600
09-Jan-22	678	32,6	645,4	15.489.600
10-Jan-22	665	31,5	633,5	15.204.000
11-Jan-22	677,0	32,2	644,8	15.475.200
12-Jan-22	680,0	32,4	647,6	15.542.400
13-Jan-22	680	33,0	647	15.528.000
14-Jan-22	665	31,9	633,1	15.194.400
15-Jan-22	684	32,4	651,6	15.638.400
16-Jan-22	677	32,2	644,8	15.475.200

From table 4, we get the net value by subtracting the auxiliary power value from the gross power value. The net power is multiplied by 24 hours of operation in one day. Therefore, we get unit net power from one day of operation.

Table 5: Total Energy Calculation

Date	Coal Feeder Total Flow	Total Coal Con-sumption	HHV	Energy
Unit	Ton/h	Ton (24 hour)	kcal/ kg	kcal
03-Jan-22	259,1	6227,2	5584	34.772.684.800
04-Jan-22	262,5	6314,5	5584	35.260.168.000
05-Jan-22	264,9	6372	5584	35.581.248.000
06-Jan-22	270,1	6468,1	5584	36.117.870.400
07-Jan-22	259,7	6238	5584	34.832.992.000
08-Jan-22	266,1	6390,3	5584	35.683.435.200
09-Jan-22	264,8	6345,8	5584	35.434.947.200
10-Jan-22	265,9	6392,6	5584	35.696.278.400
11-Jan-22	272,7	6521,0	5584	36.413.264.000
12-Jan-22	279,7	6707,2	5584	37.453.004.800
13-Jan-22	282,5	6769,7	5584	37.802.004.800
14-Jan-22	278,3	6680,4	5584	37.303.353.600
15-Jan-22	272,9	6548,2	5584	36.565.148.800
16-Jan-22	273	6563,9	5584	36.652.817.600

From table 5 we can obtain the total energy by multiplying total coal consumption which operates 24 hours in one day and HHV caloric value.

Table 6: NPHR Calculation

Date	NPHR
Unit	kcal/kwh
03-Jan-22	2275,58
04-Jan-22	2267,943
05-Jan-22	2281,902
06-Jan-22	2314,536
07-Jan-22	2290,318
08-Jan-22	2296,586
09-Jan-22	2287,661
10-Jan-22	2347,822
11-Jan-22	2353,008
12-Jan-22	2409,731
13-Jan-22	2434,441
14-Jan-22	2455,073
15-Jan-22	2338,164
16-Jan-22	2368,487

So, in table 6 the NPHR value is obtained by dividing the energy value (kcal) and the net power unit (kwh).

3.3.2 NPHR Change Percentage

If the NPHR value of SPP X boiler unit 4 is compared before and after injection, the following values are obtained:

NPHR value before injection (3rd January 2022)
= 2.275,58 kcal/kwh
NPHR valueafter injection (16th January 2022)
= 2.368,487 kcal/ kwh

To calculate the percentage change, it is calculated by the following formula:

ISSN (online): 2581-3048
Volume 6, Issue 8, pp 31-35, August-2022
https://doi.org/10.47001/IRJIET/2022.608005

Change(%) =

$$\frac{(\text{NPHR after injection} - \text{NPHR before injection})}{\text{NPHR Value before injection}} x100\%$$

Change(%) =

$$\frac{(2.368{,}487\ \text{kcal/ kwh} - 2.275{,}58\ \text{kcal/ kwh})}{2275{,}58\ \text{kcal/kwh}} x100\%$$

Change Presentage = 4,08 %

After calculating the percentage change of coal additive injection, the NPHR value increased by 4,08% which indicates that the treatment had no significant impact. However, the success parameters of coal additive injection are not only from the NPHR value but also from the amount of slag that falls and the hardness or softness of the falling slag. According to these 2 parameters, the injection of coal additive succeedin collapsing the slag and softening the slag attached to the walltube.

IV. CONCLUSION

From this study, several conclusions were obtained regarding the topics based on the data and calculations that have been described, such as:

1. Based on the acid-base method used to measure the slagging potential of a coal, the coal used in SPP X unit 4 is categorized as high potential slagging coal. The slagging index value is 0,5769 for Supplier A and 0,4387 for Supplier B.
2. Based on the analysis that causes slag in the boiler unit 4 SPP X, maintenance treatment that was carried out is coal additive injection. Magnesium based coal additive is used to achieve chemical reaction that causes lag peals of easily because of porosity is obtained.
3. After calculating the percentage change, coal additive injection made the NPHR value increased by 4,08% which indicates that the treatment has no significant impact rather indicating power plant inefficiency.

REFERENCES

[1] Akbar, M.S., Suryadi, F. and Prastyo, D.D., 2009. Kinerja Economizer Pada Boiler. *Jurnal Teknik Industri*, 11(1), pp.72-81.

[2] Zhou, S. dan Turnbull, A., 2002. Steam turbine operating conditions, chemistry of condensates and environment assisted cracking-*a critical review*.

[3] Suarez-Ruiz, I. dan Crelling, J.C., 2008, *Applied Coal Petrology, Elsevier, Burlington*.

[4] Handayani, R.H.E., 2019. ANALISIS PENGARUH KUALITAS BATUBARA UMPAN TERHADAP POTENSI SLAGGING PADA BOILER CIRCULATING FLUIDIZED BED (CFB) DI PLTU BANJARSARI 2 X 135 MW. *Jurnal Pertambangan*, 3(1), pp.36-43.

[5] Felani, A. and Al-Janan, D.H., 2021. Analisis Statis Konstruksi dan Lance Tube Sootblower Tipe Motorised Rotary Menggunakan Software Solidworks 2016. *Jurnal Rekayasa Mesin*, 12(2), pp.243-250.

[6] Lin Xiaojuan: "Supply Guangzhou Gaowang High-energy Coal-Saving Combustion Booster", Zhiqu.com, 7 November 2011 (2011-11-07), *hal.* 1 – 3.

[7] PT Regi jaya "Peningkatan clean Heating surface & pengendalian abu (slagging/fouling).

[8] Nainggolan, S.A., 2021. Analisa Peningkatan Nilai Net Plant Heat Rate (NPHR) pada Unit 1 PLTU Tenayan 2 x 110 MW. *Jurnal Surya Teknika*, 8(1), pp.259-264.

Citation of this Article:

Muchammad, Yosef G P Napitu, Budi Setiyana, "Net Plant Heat Rate (NPHR) Analysis of Main Plant Boiler Unit (UIK) Towards Coal Additive Corint PC 99 Injection", Published in *International Research Journal of Innovations in Engineering and Technology - IRJIET*, Volume 6, Issue 8, pp 31-35, August 2022. Article DOI https://doi.org/10.47001/IRJIET/2022.608005

****