Analysis of the Coal Milling Operations to the Boiler Parameters

Salmi Samsudin, Nuraini Abd Aziz, Mohd Adzuan Che Azmi

Abstract: Fuel and firing system purposely to deliver light fuel oil or coal as one of the primary elements of fuel in an ideal condition for combustion to take place in the boiler combustion chamber. Milling system in coal power plant purposely to process the raw coal to become as pulverise fuel before enter to the boiler furnace. Pulverise fuel enter to the boiler furnace through pulverise coal pipe (PC) which attached to the boiler. The different mill has different PC pipe corners, and with different length and high level. This case indicates and measures the changes of boiler parameters due to different mill in service.

The results show, the highest mill in service not affected to the boiler parameters such as reheater metal temperature, main steam temperature and boiler flue gas outlet and others boiler parameters during combustion process. The results also presented thru empirical data where it showed that the distribution of pressure, temperature, velocity at the boiler is equalized. The operating of mill parameters during the research carried out is monitor closely to avoid explosion to the mill. Besides that, the size of the PF as a main fuel is measured to ensure complete combustion in the boiler furnace. The results indicate the optimum arrangement of the mill operation with minimum boiler parameters affects.

Index Terms*: *Combustion, Milling System, Pulveriser, Boiler parameters.

I. INTRODUCTION

Chikkatur, Sagar, Abhyankar, and Sreekumar, (2007) mentioned that the increase of demand in electricity by using coal as the main fuel due to several advantages such as coal technologies with advance engineering and good operational practise. With the lowest price compare to the others type of fuel, the coal is selected as the main fuel for producing electricity.

Kuo, (1986) discussed the basic need of combustion such as fuel, source of heat and the need of air combination together in the furnace. For combustion to take place in the boiler combustion chamber, three primary elements of fuel, air and heat source must be presented. The fuel & firing system describes the types of fuel and the systems to deliver the fuels to the furnace.

National Aeronautic and Space Administration (NASA), (2015) described the combustion is the chemical reaction in which an element reacts rapidly with oxygen and gives off heat. Slightly the element called the fuel, and the source of oxygen is called the oxidizer to perform a combustion process. Querol, Fernández-Turiel, & López-Soler, (1995) mentioned the trace elements in coal and the coal behavior during combustion in a large power station were characterized by the coal content and distribution in the fuel.

As mentioned by Smith, (1982), the needs of research in coal combustion due to correlation between coals mass transfer and intrinsic affect to perform a complete combustion. Smith, (1982) also commented that the raw coal and combustion process will cause the volatilization of the coal and cause the reducing of coal performance. Therefore, coal as the primary fuel and play the important roles in controlling the combustion process in the furnace. As discussed by Kuo, (1986), the heating surface is one of the elements contributes to the combustion efficiency and correlated to the fire ball in the furnace. Pulverised fuel is the main element for combustion in the furnace. The pulverizers and burners system provides pulverized coal to the boiler as primary fuel. Coal enters the plant from the coal handling system where it has been crushed to consistent sizes where it can be handled by the pulverizers. It is delivered to the coal bunkers which are located directly above their respective pulverizers, also called mills.

By referring to Mill which refers to grinding equipment in Wikipedia, the free encyclopaedia (2016), a mill is defining as a machine purposely to process the material into smaller sizes through grinding, crushing or cutting. Basically there are three different types of pulverizing which are attrition, crushing and impaction. Attrition type, where material is ground by rubbing or friction to produce the end product. Crushing pulveriser is where the material is forced between two fixed objects and impaction pulveriser by processing the material at the ground is by hitting or impacting through the outside forced. As discussed by Mular, Andrew, Halbe, Doug, Barratt, Derek (2002), the selection of mill or pulverising process are depend on the types of material and mineral. Mular, (2002) stipulated that the process of milling or pulverising is required high energy for producing fine particle size reduction.

As mentioned, milling system exactly purpose to produce pulverise fuel as end product. The mill main component such as mill roller, grinder and mill motor was design to suit with the end product. Most Pulverized fuel (PF) mills are taken from manufacture stock designs and adapted to fulfil the requirements of a particulars application. The capacity of the mill end product to supply the fuel to the boiler furnace already calculates to ensure the optimization of boiler operation. By doing that, the

Revised Manuscript Received on June 5, 2019.

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amount of PF required for the combustion correspondent and co related to the boiler combustion capacity. To ensure the coal performs good combustion, milling system is required to tune the coal sizes. Wen, Wang, and Zhang, (2010) mentioned that the need to carried out the study to ensure the milling system perform well and optimizing the milling controller. Wen, (2010) concludes that the mill performance in term of coal end product is the major factor can cause the plant performance through the combustion in the boiler furnace. According to Wei, Wang, and Wu, (2007) the design mill depends on the coal in use. In general, factors affecting the choice of mill design are Hardgrove Index (HGI) which is ash content and total moisture of the fuel to be processed. It's also depending on the purpose of milling system and the capacity of the mill production.

Due to different arrangement of mill in service, the fire ball position slightly will be different. The length of the PC pipe and the mill transportation factors such as air supply and distance will affect the combustion process. Therefore, there are high possibilities that the boiler parameters such as reheater metal temperature, main steam temperature and boiler flue gas outlet will be disturbing due to the changes of fire ball position.

The changes in boiler parameters will cause the efficiency of the boiler decrease. The boiler generation will be derated at sentence limit to ensure the operational wise not interrupted. As mentioned by CEA (2005), Khanna and Zilberman, (1999), Shukla, Biswas, Nag, Yajnik, Heller, Victor, (2004) the low generation efficiency is commonly due to variety of technical and maintenance factors such as coal quality, grid transmission line, low Plant Load Factor (PLF), aging and plant reliability, improper of operation and maintenance at power plants, design and engineering, government policy and guidance, and restructuring of tariff structure and encouragements. Campbell, (2013) stipulated that all the components attached to the power plant generation encompass the plant performance and plant efficiency.

II. MATERIAL & METHODS

The study was carried out at coal thermal plant generation which is producing 700MWn. The boiler design operating as sub-critical and attached with reheater. At temperature 5400C with 175bar pressure, the superheater main steam is executes and rehater steam performs at 5400C temperature with pressure 38bar. Coal is the primary fuel during normal boiler operation while light fuel oil is used during boiler start-up or during low load operation below 40% of Boiler Maximum Capacity Rate (BMCR). The boilers are designed to fire subbituminous coals. During the test, the same group of coal brand and specification in use. The combustion circuit consists of a single furnace, with direct tangential firing and balanced draught.

Coal Specification	Coal Parameters
Calorific value (kcal/kg)	4852
% Carbon	73.3
% Hydrogen	5.18
% Nitrogen	0.93
% Oxygen	20.43
% of Ash	2.5
% of Moisture	29.0
% of Sulphur	0.16
HGI	47

The coal milling plant consists of 7 vertical bowl mills. The firing equipment consists of seven elevations with 28 coal burners positioned above or lowers fuel oil burners (OB). The boiler is design producing 100% of BMCR by firing coal through full capacity of coal burners. The seven individual milling systems is design for this power plant where its functions to grind the raw coal to become pulverised fuel. Besides that, mill system to ensure the continuously supply pulverised coal to the firing system of the boiler. Each milling circuit is independent and includes:

1. Single bunker of raw coal storage with maximum 608 tonne capacity
2. Single raw coal feeders at maximum flow rate 70 t/h capacities.
3. Single bowl mill, type BCP2820 and driven by a 750 kW motor
4. Oil skid purposely as the lubrication for the reducer
5. Oil skid purposely to the mill journal hydraulics systemAuxiliary steam supply for inerting circuit

From the coal yard, the coal is transfer to the mill bunkers through conveyor belt. The bunkers are sized for an effective capacity of twelve (12) hours at BMCR with design coal. Each mill bunker has one hopper, connected to the feeders.

Mills operate when the bunker coal gate valves are opened, coal is allowed to flow to the gravimetric feeders. The flow of coal from the feeders is controlled to maintain the desired load. From the gravimetric feeders the coal is fed into the pulverizers. Within the pulverizers the coal is ground, dried, and classified to the proper size for burning in the boiler. The primary air flow carries the fine coal to the burners, and the coarse coal falls back into the grinding zone of the pulverizer. Fig. 1 shows the main component in the milling system and the position of typical arrangment.

The mill design in the power plant is a vertical bowl. The mill rotated on his axis at minimum speed 35rpm by a motor-reducer train. The grinding rolls are supported by three oscillating journals. The rolls rotate freely crushing the coal on the bowl, the pressure for optimal crushing being modulated by maintaining adequate coal layer thickness on the bowl. This thickness is measured by a special sensor detecting the displacement of the journals. The signal is used to modulate the pressure of the rolls by controlling oil pressure (Alstom Operation and Maintenance Manual Revision B, 2003).

For a given mill load, the total Primary Air (PA) is kept constant. This flow ensures the transport of the pulverised coal to the burners and the correct speed in the Pulverised Fuel (PF) pipes. To prevent fire risk, it is important to avoid coal deposits in the PF circuits.

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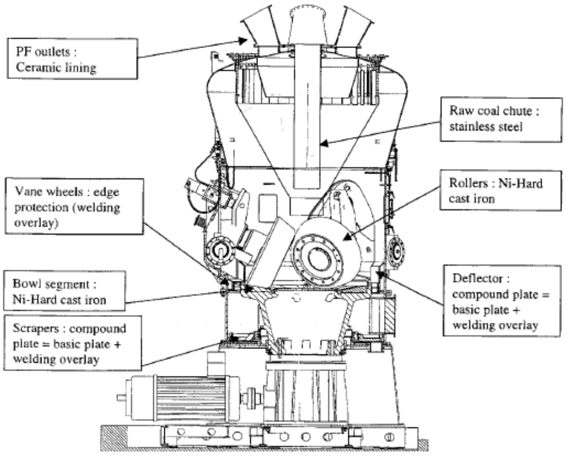

Fig. 1: Typical arrangement of a vertical bowl mill

Primary air is admitted through the mill, which carries the finest coal particles to mill outlet. The air and coal mixture passes through a classifier, located at the upper part of the mill, where an additional particle separation takes place. Coarser particles return to the coal chute and fine particles are carried to the classifier outlet. The classifier has four (4) outlet pipes, and feeds one level of coal burners.

The four air control dampers at the inlet of the mill control the mill outlet temperature at 70 °C by mixing hot air with cold air and control the total primary air flow through the mill. The air enters the pulverizer through nozzles in the air pot ring, which surrounds the grinding table to dry and transport. As the coal is pulverized on the grinding table, the air carries it up to the classifying section of the pulverizer (Alstom Operation and Maintenance Manual Revision B, 2003).

Classification of the coal begins in the area above the pulverizer throat. Primary air exist the airport nozzles, picking up pulverized coal, and exits the grinding zone in swirling motion. This swirling action, along with gravity, causes the larger, heavier particles of coal to fall out of suspension and back into the grinding zone. As the pulverized coal and air mixture passes through the classifier, the finer particles of coal are discharged through a distributor or called as pulverised coal pipe (PC) and to the burners (Alstom Operation and Maintenance Manual Revision B, 2003).

Fig. 2 shows the position of mills attached to the boiler. The boiler tubes arrangement also clearly structure and correlated to the flue gas direction. Ge, Bai, Liu, Zhu, Wang, Qing, & Zhang, (2001) mentioned that, the arrangement of the boiler tube is based on the gas circuit flow and distribution to ensure sufficient heat transfer in the furnace.

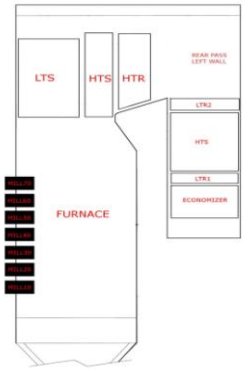

Fig. 2: Mills position attached to the boiler furnace

Table 2 describe the mill specifications in used for this test. All the mill component parameters such as mill bowl, mill journal, and mill motor mentioned in the table also. All the attached mills have the same specification and characteristic.

Table 2: Mill specification attached to boiler

No	Descriptions	Parameters
1	Number of Mill per boiler	7
2	Type of Mill	Vertical bowl
3	Mill capacity with coal B typical	68 t/h
4	Mill capacity with coal B worst	66 t/h
5	Number of grinding Journal	3 (with splash lubrication)
6	Grinding journal diameter	1730 mm
7	Material of rollers	ALSTOM-Nihard 4 (regenerable)
8	Weight of grinding journal	12400 kg
9	Bowl diameter	2800 mm
10	Bowl speed rotation	35 RPM
11	Material of grinding segment	ALSTOM-Nihard 4 (regenerable)
12	Weight of bowl-assembly	20800 kg
13	Motor shaft speed of rotation	1000 RPM
14	Motor rating	750 kW
15	Type of classifier	static classifier with manual adjustment of classifier guide vanes
16	Number of outlets classifier	4
17	Type of gearbox	FENDER KMP320

The seal air circuit in the milling system purposely to ensure the entire air content suck to the milling system properly covered. Attached with seal air circuit is a motorized seal air fan operating in conjunction with the mill, a discharge manual shut-off damper, a local pressure indicator. A differential pressure measurement was installed to get between the seal airline to the mill and the upper part of the mill at classifier inlet.

The mill journal hydraulic system is design to control the mill rollers operation. The journal oil pressure has a set point adjustable between 25 and 60 bars. The usual set point is setting between 15% to 43 % gap in corresponding to the hydraulic pressure at 30 to 40 bars. The system mill journal hydraulic system includes:

1. One main oil tank divided in two parts

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(return side and main pumping side) with:

a. One immersed oil pump with discharge safety valve driven by an electric motor
b. One transfer and filtering unit between return side compartment of oil tank and main pumping side. This unit includes a motorised pump and a filter with clogging detector switch to measure the differential pressure
c. The necessary instrumentation of the oil tank including level and temperature indication and low level switch detector.

2. The oil line filtering assembly with two filters and associated clogging detector
3. An oil pressure stabilizer with accumulating chamber and the necessary pressure indicator and switch for monitoring and control
4. The oil "ring" modulating flip/flop valve which purpose is to stabilise and modulate the oil pressure in the ring thus in the journals accumulators for spring effect adjustment.

The mill main gear box lubricant consists of the main motor gear crank case which contains the reserve of oil. It is fitted with level indicators and temperature measurement. The system also attached with one pumping station with the necessary inlet shut-off valve, motorised pump, relief safety valve and discharge check valve (Alstom Operation and Maintenance Manual, 2002). One oil filtering unit installed with a set of two changes over filters, fouling detector and by pass discharge protection with a switch in case of operation. To ensure good performance of lubricant oil, an oil cooler with water cooling medium circuit is occupied also. The basic necessary instrumentation for checking oil temperature, pressure and flow commonly installed to the system.

The boiler is design for tangential firing in the furnace. The arrangement of the oil burner and coal PC pipes as shown in Fig. 3. The boiler furnace at this power plant has a section of 19.5 wide x 18.4m depth dimension. The pulverised fuel and the combustion air are entered through the corners of the furnace pipes. Razali, Boosroh, Hasini, Shuaib, (2009) mentioned the tangential burner firing on angle by following an imaginary line tangent to a small circle located in the centre of the furnace.As stated by Razali, (2009) the additional mixing of fuel and air flow provides a rotation motion to the flame and creates additional turbulence in the furnace. Then, "fire ball" come to the take place the flame spreads in the furnace. The system allows the fuel particle to have sufficient time for residence in the furnace, which is beneficial for the combustion.

Seven elevations of Pulverised Coal (PC) burners are provided. The Pulverised Coal burners, the OB and the Air Nozzles are arranged in vertical layers. Fig. 3 illustrated the arrangement of PC, OB and SA at the boiler elevation. Razali, (2009) stipulated also each Pulverised Coal burner consists of an individual chamber connected to the PC pipe. All the burners and air nozzles can be tilt and adjusted in the same time to raise and lower the "fire ball" in the furnace. The position of the "fire ball" expressly to control the heat absorbed in the walls and in the radiant elements (Alstom Operation and Maintenance Manual, 2002).

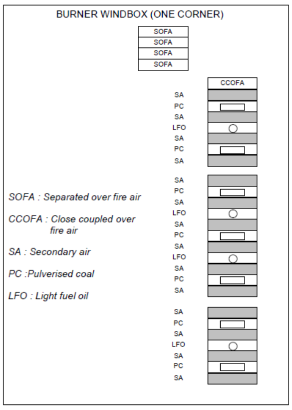

Fig. 3: The arrangement of PC, OB and SA at the boiler elevation

III. RESULT

Table 3 shows the average parameters of the operational mills in service on producing load 700MW. The mill number 10 in standby mode which is not in service and the others mills is in service. The mills in service using the same types of coal brand.

Table 3: Average mill operating parameters with mill 10 in standby mode

Parameter	Mill						
	10	20	30	40	50	60	70
Coal mill motor power (kW)	0	417.1	454.8	439.0	458.6	456.2	441.0
Mill motor current (Amps)	0	86.6	92.6	89.7	94.7	94.0	90.4
Feeder coal flow (Tonne/hr)	0	56.8	56.5	56.4	56.4	56.6	56.3
Mill PA corrected inlet flow (KNm3/hr)	0	101.9	102.4	101.4	101.5	101.6	102.3
Mill PA inlet temperatur e (◦C)	35	273.7	285.9	255.9	289.2	305.3	286.3

The monitoring of the coal mill power and mill motor current is purposely to ensure the loading for the mill motor is within the limits. Loading on motor power means the energy required to grind the coal to perform as pulverise coal (PC). The end product of the PC sizes is about 20-30 µm before transport into the boiler. The feeder coal flow is measuring the speed of the coal into the boiler. In this case. The Primary Air (PA) inlet flow is the air flow required to transport the PC into the boiler. The flow must be equalizing distributed between four corners of the PC pipe to ensure the velocity of the coal

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flow is the same. Meanwhile the PA inlet temperature measured the hot air goes into the boiler. The PA flow is purposely to convey pulverized coal from mill to burners and to provide primary air for boiler combustion, (Alstom Operation and Maintenance Manual, 2002).

Table 4 described the sequence of mills in service in order to performance 700MWn. All mills firing with the same type of coal for at least 3 days without interruption. The boiler parameters recorded accordingly.

The boiler parameters recorded such as final superheated outlet which is indicate the superheated steam condition and the ideal reading for the superheated steam temperature is 540˚C. Besides that, the superheater water injection and reheater sparay water flow are indication of water flow require to meet the superheated temperature and reheater temperature. The highest water flow means the superheated steam and reheater steam temperature is high and need more water to cool down the temperature. From the results showed that the water flow requires is almost the same. By looking at the furnace rear path temperature, is measuring the flue gas outlet from the furnace at the rear path area. Highest furnace rear path temperature significantly will gives highest temperature for the flue gas outlet and affect to the gas recirculation system and heat transfer process at the heater. Form the reading, observed that the highest mill in service not influence the furnace rear path temperature.

Table 4: Boiler performance and mill in service

Boiler parameters	**Standby Mill Number**						
	10	**20**	**30**	**40**	**50**	**60**	**70**
Measured MW (gross) (MW)	739	734	737	735	729	733	730
Measured MW (net) (MW)	692	686	689	688	682	683	684
Final superheater outlet temperature (1) (˚C)	541	540	540	538	539	543	539
Final superheater outlet temperature (2) (˚C)	541	539	540	539	540	543	540
Superheter water injection compensate flow (Tonne/hrs)	128	116	106	119	130	125	156
Reheater spray water flow (Tonne/hrs)	0	0	0	1	2	0	2
Furnace rear path temperature (1) (˚C)	743	741	755	781	796	762	769
Furnace rear path temperature (2) (˚C)	714	755	790	765	798	820	781
Left side Regenerative Air Heater outlet flue gas temperature (˚C)	165	169	169	175	181	173	173
Right side Regenerative Air Heater outlet flue gas temperature (˚C)	166	166	176	174	182	175	175

IV. CFD ANALYSIS

Fig. 4 shows the boiler geometry used for this analysis of coal milling arrangement. The boiler geometry designed based on the boiler parameters original design by the manufacture. In addition, position of the burner and pulverised coal (PC) pipe stated in the boiler geometry.

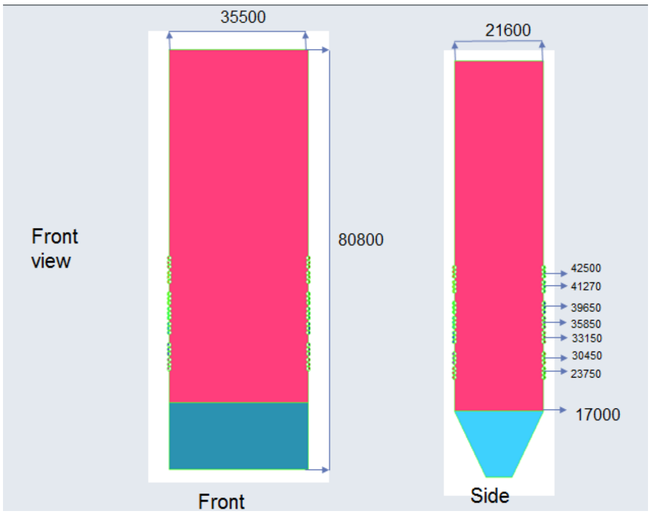

Fig. 4: Boiler geometry

Fig. 5 shows the pulverised coal pipe position which is present the mill arrangement at the boiler level. There is 28 PC pipes involves in the analysis which located at 4 corners at the boiler. However, only 24 pipes in service for each of analysis at one time.

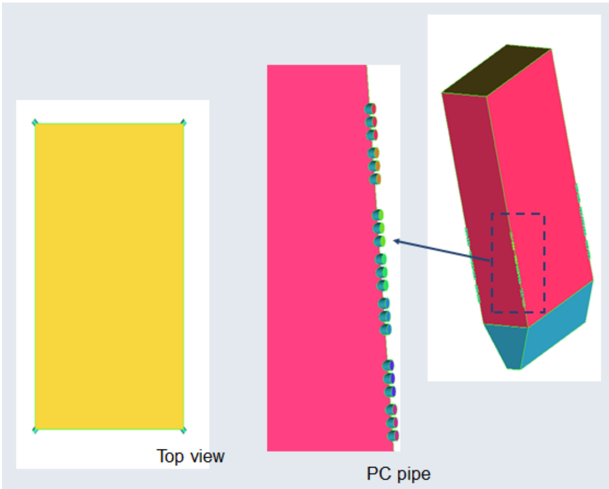

Fig. 5: Pulverise Coal position

In order to run the analysis, the input for the boiler parameters is the essential elements. Fig. 6 shows the boiler geometry and the parameters involves which are consists of primary air flow, temperature for primary air flow, secondary air flow, temperature for secondary air flow, coal flow and coal flow temperature.

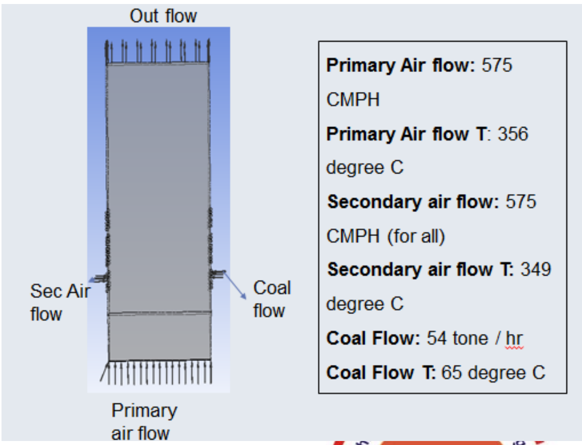

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Fig. 6: Boiler geometry and the parameters involves

Fig. 7 represent the velocity distribution in the boiler while PCs pipes at level 1 are not in service. In the meanwhile, the others PC still in service and produced 700MWnett. From the CFD analyses results there are produce the same velocity contour for each of the analysis.

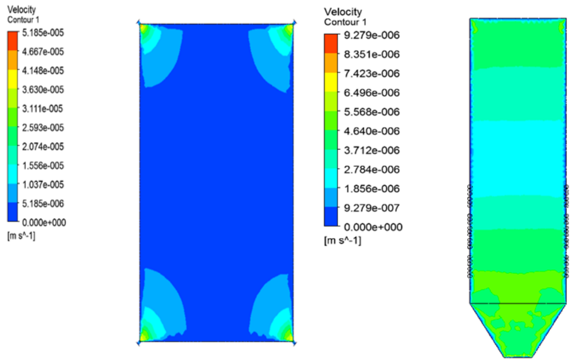

Fig. 7: Velocity distribution top and front view.

Fig. 8 represent the velocity distribution in the boiler while PCs pipes at level 1 are not in service. In the meanwhile, the others PC still in service and produced 700MWnett. During the experiment boiler pressure must maintain at -1 mbar in order to perform fire ball in the furnace. However, from the CFD analyses results there are produce the same pressure contour for each of the analysis.

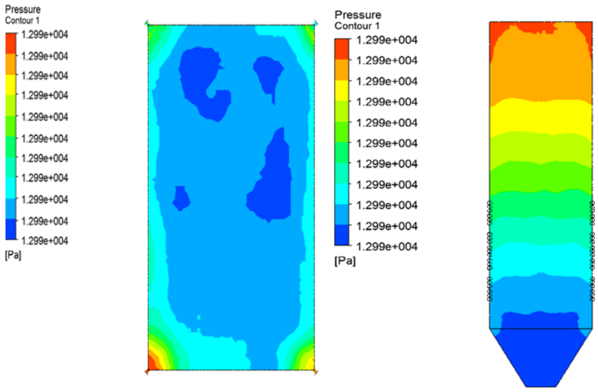

Fig. 8: Pressure distribution top and front view.

Fig. 9 represent the temperature distribution in the boiler while PCs pipes at level 1 are not in service. In the meanwhile, the others PC still in service and produced 700MWnett. During the experiment the primary air temperature is 356ºC and secondary air temperature is about 350°C for all analysis. CFD analyses shows results there are no different temperature contour for each of the analysis.

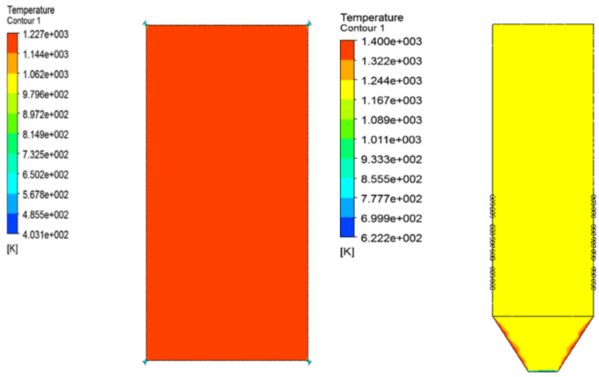

Fig. 9: Temperature distribution top and front view.

V. CONCLUSION

Pulverizing the coal to a fine powder is an important function in the operation of a power plant. This article explains the process of raw coal become the pulverise fuel (PF). The key input to the coal fired power plant is the coal. Coal in the form that is available from the mines is not suitable for efficient combustion in the boiler of the power plant. The pulverizing system prepares the coal for combustion. Besides that, the level of the PC pipes, velocity of primary air and secondary air, oxygen contents and boiler pressure influence the boiler performance. In this case, the level PC pipes in service not much effect to the boiler performance.

Factors governing the operation and performance of an individual pulveriser system are many, and often very complex. Therefore, it will result and correspond to the boiler performance. This paper covers many of the practical aspects of the milling system in term of milling process and operation of milling plant and associated systems. At the same time it offers some explanations for the stringent precautions applied to the operation and maintenance plant. It is not intended to cover the complex dynamics of coal pulverisation, although some aspects are touched upon in to give a fuller understanding of the principals involved.

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