Computational Fluid Dynamics Analysis of Double flue Technology in Coke Dry Quenching

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***Abstract*— In this Project CFD simulation COKE DRY QUENCHING is simulated using ANSYS CFD software. In this Simulation CFD modeling is done using ANSYS Design Modeler. CFD meshing is carried out using ANSYS Meshing Platform, in this project tetrahedral with prism boundary layer meshing is used. Simulation is carried out for single and double gas entry COKE DRY QUENCHING. Then finally both the results are compared in terms of temperature, pressure drop, velocity and streamlines contours.**

Keywords*— computational fluid dynamics, coke dry quenching, double flue, temperature, pressure drop, velocity and streamlines contours.

I. INTRODUCTION

JSW Steel Limited has embarked upon a new approach to conserve both heat energy and fresh water, abate air and water pollution associated with the conventional wet quenching process during manufacture of metallurgical coke. JSW Steel Ltd has four number of CDQ facility at its Vijayanagar Works Plant. CDQ facility at JSW is more advanced, mature and reliable technology to make dry quenched metallurgical coke.CDQ is a system to quench the red hot coke and recover sensible heat of hot coke by using inert circulating gas. This recovered heat is fed to boiler, which generate high temperature and high pressure steam. This steam produced without any additional energy is used for the generation of electric power.

TABLE I.CDQ Specifications

Maximum coke throughput	120 t/hr
CDQ facility in Coke Oven # 3	120 t/hr x 2
CDQ facility in Coke Oven # 4	120 t/hr x 2
Red hot coke temperature	1050°C
Cooled coke temperature	< 200°C
Boiler steam production capacity	Max 72 t/hr
Steam pressure	9.5 Mpa
Steam temp	540+-5°C
Circulation gas volume	Max 180,000 m^3/ hr
Circulation gas temperature at boiler inlet	970°C
Circulation gas temperature at cooling chamber inlet	130°C

To protect the circulation fan from abrasion, SDC consists of set of cyclones to separate fine dust. Now this cleaned circulating gas is again charged into the chamber. Dust collected from PDC and SDC in collected into a dust hopper and discharged to yard with the help of tipper.

TABLE:2 Circulating Gas Composition (by Volume %)

Circulating Gas Composition (by Volume %)	
CO_2	15%
H_2O	8%
O_2	<1.0%
CO	0.1%
H_2	0.3%
Dust content, g/ NM_3	8-12%
N_2	70-75%

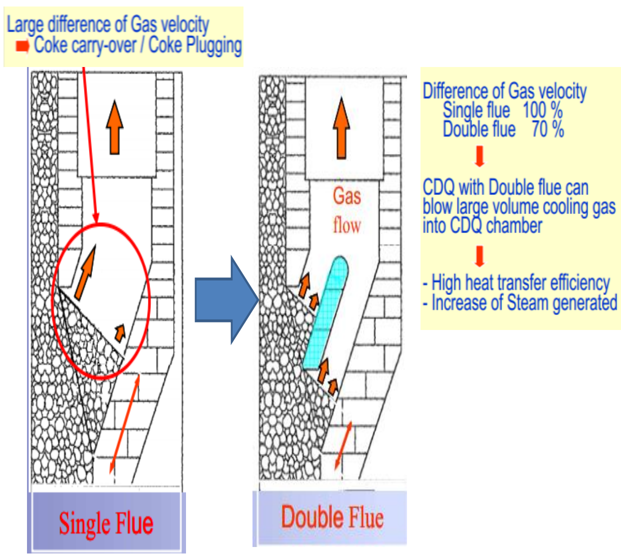

Fig.1 Distinguish between Single & Double flue

During this hot coke charging process into CDQ chamber, locomotive runs to receive hot coke from next oven. Again locomotive with hot coke bucket approaches CDQ chamber and firstly centers empty carriages underneath the crane and receive empty bucket first and then centers carriage with hot coke bucket under the crane to charge hot coke into CDQ chamber.

While charging hot coke bucket into the chamber the top cover of charging facility is opened automatically by motorized cylinder, and charging hopper provided with bell is set at the center of chamber. Next, the bucket is lowered and placed on the support installed at both sides of charging hole. In addition, when the charging crane descended, the gate under the bucket is opened, and charging of hot coke is started. When the charging is completed, top cover is closed automatically, and the bucket is returned to the initial position on the carriage. During hot coke is charging process, charging facility is connected to de-dusting duct so as to collect all the coke dust generated. The charged hot coke (Max.1050°C) is cooled down to 200°C or below with the circulating gas in chamber and discharged to coke conveyor by discharging device (Vibro-feeder and RSV). Circulating gas is supplied through sub-economizer to blasting device installed at the bottom of chamber. This circulating gas is divided and uniformly distributed in central and the peripheral of cooling chamber. In cooling chamber, circulating gas is heated to approx. 970°C and fed to primary dust catcher (PDC) through sloping flue installed at the boundary between cooling chamber and pre-chamber. In PDC, bigger size of coke dust is separated. After passing through the PDC, circulating gas goes to boiler, where its sensible heat is recovered, and high-temperature and high-pressure steam is produced. This high-temperature and high-pressure steam is utilized for generating power. Before the gas goes back to circulation fan, fine coke dust particles are separated from circulating gas in secondary dust catcher

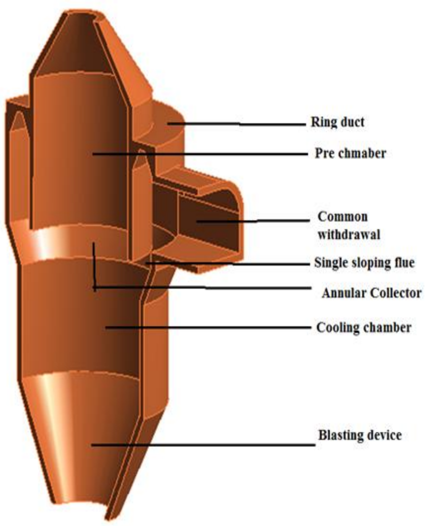

Fig.2 Single flue CDQ Chamber

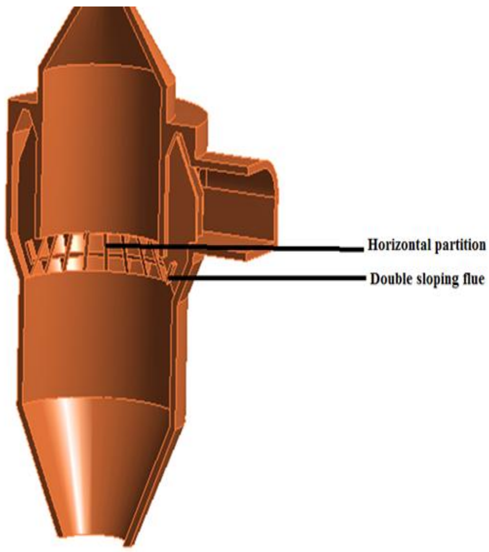

Fig.3 Double flue CDQ chamber

II. SINGLE FLUE GAS QUENCHING

Pressure is directly related to height, so pressure is more at the height and decreases as we move down. But the pressure at the sloping flue is around 36Pa which is not enough for uniform quenching of the coke so more circulating gas is

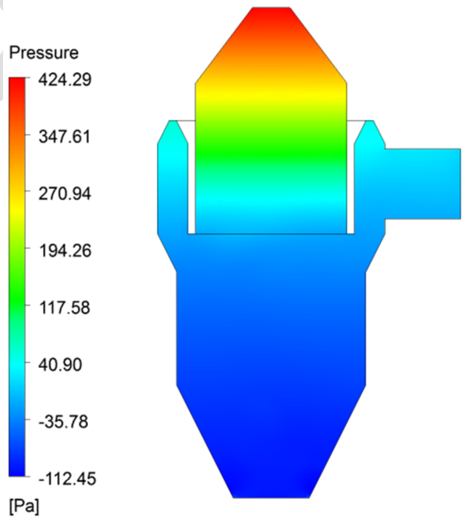

Fig.4 Pressure contours of CDQ Chamber

In the below fig.5 we can see that there is only one recirculation region of gas which is not sufficient for enough quenching of coke. The more quenching of coke can be done if their still more recirculation regions

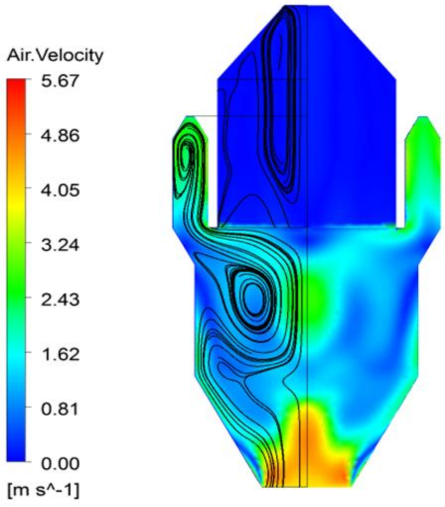

Fig.5 Velocity contours on horizontal plane showing recirculation region

In the below figure 6 we can see that coke temperature only at the peripheral region of the common withdrawal is quenched to the maximum but at the other region it is not so. Because of this more recirculation of gas is blown to remedy this changing in design of the chamber near the annular collector of common withdrawal by adopting double flue technology pressure within chamber is completely equalized near the annular collector so that uniform quenching of coke takes place, the recovered more heat efficiency takes place which can send to waste heat boiler

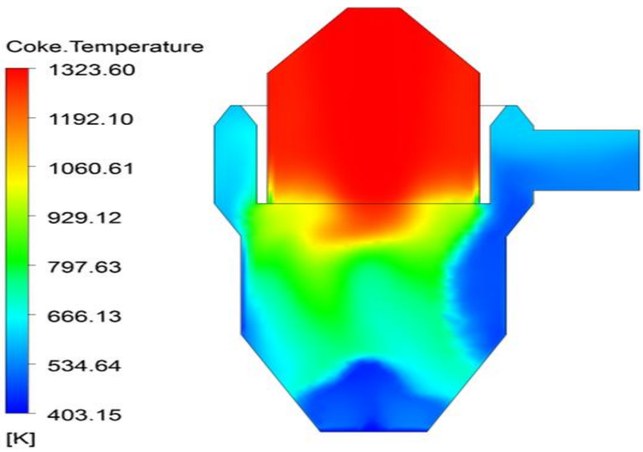

Fig.6 Coke temperature contour on symmetry plane of the CDQ chamber.

In the below fig 7 we can see that the air temperature is rising from bottom to top, but not that in case of DDQ it is raised in the middle of the chamber and below that it is maintained constant.

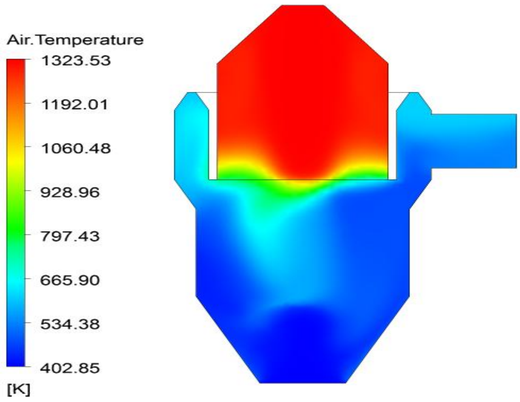

Fig.7 Air temperature on symmetry plane of CDQ chamber

III. DOUBLE FLUE GAS QUENCHING

A coke dry quenching apparatus comprises a vertical chamber in the lower portion of which, is disposed a quenching gas feeding means. The chamber has in its roof a charging hole and in its bottom a discharging gate. In the walls of the chamber is disposed a plurality of peripheral gas conduits communicated with the inner space of the chamber and with an annular collector having a common gas withdrawal conduit. According to the invention the hollow of the collector is divided by a horizontal partition provided with ports into two cavities communicating with one another, the lower cavity being communicated with the peripheral gas conduits and the upper one with the common gas with drawer conduit.

Due to the fact that the pressure of quenching gas in the lower cavity of the collector is equalized, the proposed apparatus ensures that the quenching gas flow rate through all the peripheral gas withdrawal conduits is practically equal, which provides for a uniform cooling of the whole mass of the coke being treated. This permits the consumption of quenching gas to be reduced, and the efficiency of the process to be raised.

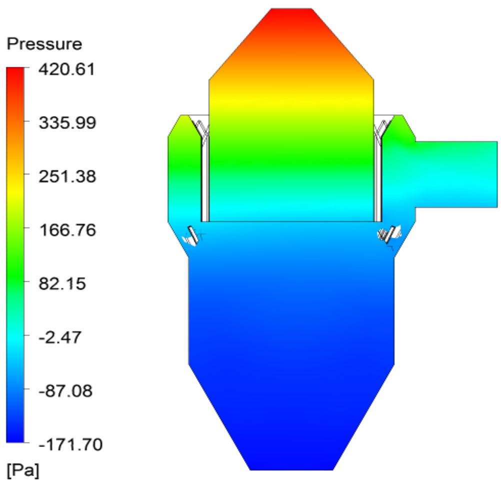

Fig.8 pressure contour on symmetry plane of CDQ chamber

Fig.9 shows that the Velocity contours on Symmetry Plane. It has been established, however, that the amount of the quenching gas passing through the peripheral gas conduits disposed close to the common gas withdrawal conduit than through the peripheral gas conduits remote there from, which is due to the fact that the pressure in the collector is minimal in the zone close to the common gas withdrawal conduit and increases with the increase of a distance there from, which is responsible for that a portion of the coke being treated is not sufficiently cooled. To remedy this, more quenching gas is blown, thereby affecting the efficiency of the process.

It is clear, that this disadvantage could be removed by means of a proportioned removal of gas from each individual peripheral conduit through an individual vacuum pump. This, however, is not advisable, since a relatively great number of the peripheral gas conduits (15-30) would involve a more complex construction.

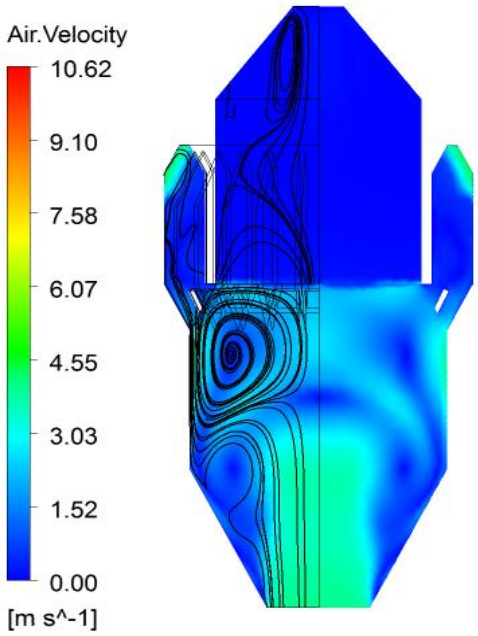

Fig. 9. Velocity contour on horizontal plane of CDQ Chamber

In below fig 10 we can see that coke temperature is almost quenched in half section of CDQ chamber and also coke is uniformly cooled at all peripheral walls of the chamber but not like in case of SDQ. The temperature of air is raised and its 1100K in DDQ. Coke is uniformly quenched near the horizontal partition.

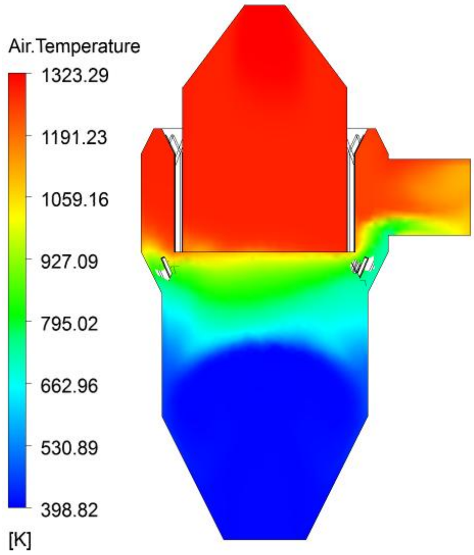

Fig. 10. Temperature contour on symmetry plane of CDQ chamber

In the below figure 11 we can see that the air temperature is gradually raised all around the peripherals walls and the coke temperature is almost lost in middle of the chamber itself and the further more quenching is not possible and we can see that there are recirculation regions around the peripheral walls and air temperature is increased in DDQ that is 1120K.

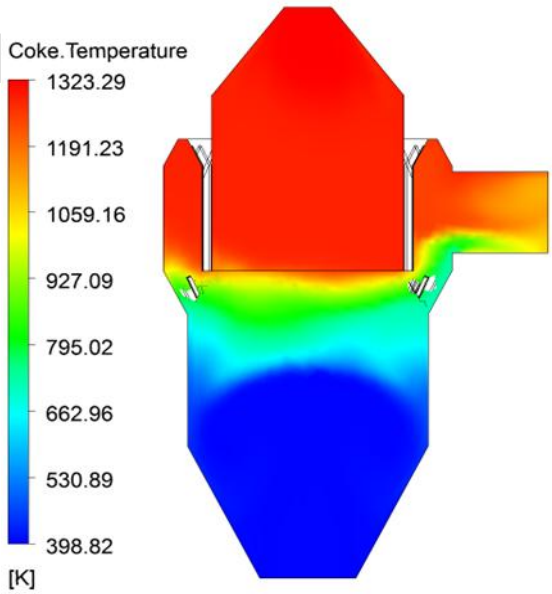

Fig.11. Coke Temperature contour on symmetry plane of CDQ chamber

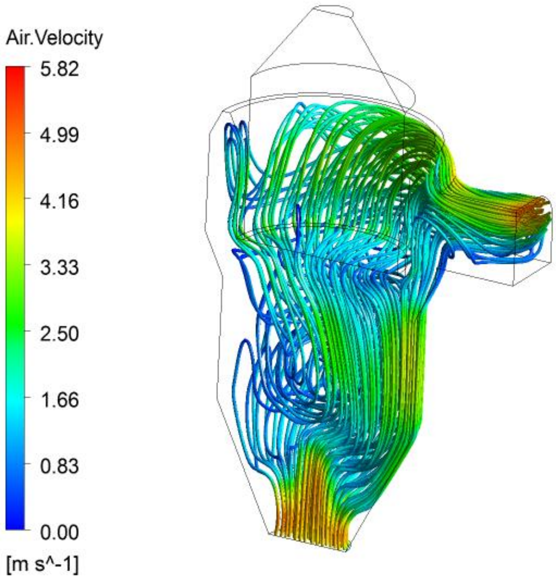

Fig.12. Velocity Streamlines of SDQ

In the above fig 12, we can see that velocity is more near the sloping flue if this velocity difference is increased more, the blow up coke take place. To remedy this velocity difference should be uniform all around the annular collector.

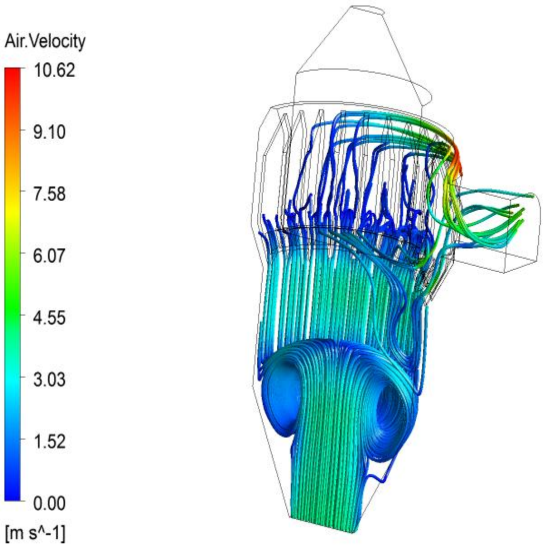

Fig.13. Velocity Streamlines of DDQ

In the above fig 13, we can see that air velocity is distributed uniformly all around the peripheral wall. If the velocity is increased there is no blow up of coke because of uniform distribution of pressure all around the walls

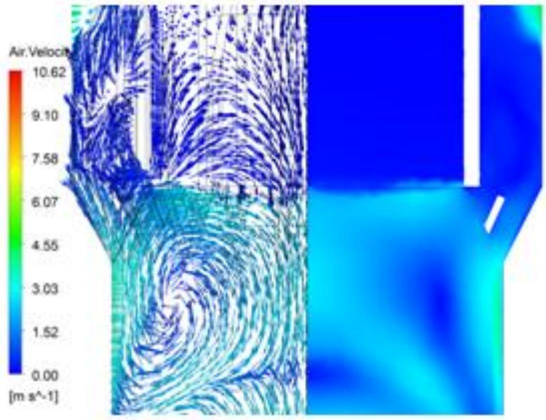

Fig.14 cut section view of Velocity vectors on horizontal plane showing direction.

CONCLUSIONS

1. The velocity near sloping flue in single dry quenching (SDQ) is 2.83 m/s where as in double dry quenching (DDQ) the velocity is around 4.75m/s.

2. The exit velocity at the common withdrawal conduit is not uniform where as in DDQ the uniform velocity is confirmed.
3. The more recirculation takes place in DDQ as result there will still more uniform quenching of coke.
4. The highest velocity in SDQ is 5.67m/s where as in DDQ the highest velocity is around 10.62m/s

BIBLIOGRAPHY

[1] **Lan-yi Sun, Yong-duo Liu, Cheng Zhai, Hui Zhou** , PROCESS SIMULATION OF AN INTEGRATED COKE DRY QUENCHING COMBINED GASIFICATION, Petroleum & Coal 54 (1) 34-41, 2012
[2] **Jingying Zhao**, Thermo Mechanical Simulation of the Flue in Coke Dry Quenching Technology, Advanced Materials Research (Volumes 255 - 260), May, 2011.
[3] **Marcelo Risso Errera, Luiz Fernando Milanez**, Thermodynamic analysis of a coke dry quenching unit, Energy Conversion and Management, 01/2000; 1(2):109-127.DOI: 10.1016/S0196-8904(99)00090.