International Journal of Research in Advent Technology, Special Issue, May 2018
E-ISSN: 2321-9637
3rd National conference on "Emerging Trends in Mechanical Engineering" (NCETM -2018)
Available online at www.ijrat.org

Increasing the Efficiency of Slag Granulation Plant in Blast Furnace

Jaganath M Peerje
Adichunchanagiri Institute of Technology Chikamagalur, 577102 (VTU, Belgaum)
Under The Guidance of Nihar Patra (Deputy Manager Mechanical).

Abstract- JSW (Jindal steel work) STEEL LIMITED is a part of the O.P.JINDAL GROUP; the group is one of the largest steel producers in the country having one of the units in Karnataka at bellary district, toranagallu. JSW STEEL LIMITED is a 10 MTPA Integrated steel plant. At present four numbers blast furnace is installed in this plant. BLAST FURNACE #1 having a capacity of 0.9 MTPA, BF#2 -1.6 MTPA, BF#3-3 MTPA and BF#4-3 MTPA. In the process of iron making, slag is a by product of blast furnace operation. Presently slag granulated and disposing to the ground nearby blast furnace and loading to the trucks by using pay loader and is sent to the cement plant to produce cement or sent to the wagon loading yard by trucks and then loading to the wagons once again by using pay loader to send the external customer to produce cement. Granulated slag is a excellent raw material for producing cement. The handling of blast furnace slag is very important aspect of modern blast furnace operation. Today blast furnace slag is saleable product in the market. Granulated slag is used in multipurpose such as in production of cement for the construction The process is highly flexible, compact in nature and it can be applied to any furnace configuration. Granulation, dewatering and storage of the slag can be done adjacent to the furnace or can be split up to suit at site accordingly the available plant space or logistics. Modern consideration concepts and closed loop water circuits ensure best available environmental control. The main maintenance problems are encountering in cooling tower, wear and tear of pipe lines, and slag carryover in water. These problem will be came by insufficient cooling of the water, when the water not cooled in the cooling tower, because of the recirculation of this water, the water is used again in the slag granulation process because of the high temperature of the water the slag becomes fine size. it can't be filtered in dewatering system so this slag are settled in pipe lines and its reduce the flow of water head and also jammed in small diameter distribution pipe in cooling tower hence it will decreases the cooling tower efficiency and also decreases the slag granulation plant efficiency. For increasing the cooling tower efficiency the modification will be made by constructing of channel and discharge pipe and filtering of slag in constructed channel.

1. INTRODUCTION

JSW Steels is one of the most recognised steel plants in the country. Though a site for setting up an integrated steel plant was inaugurated by Mrs. Indira Gandhi in 1971, the plan remained a non-starter till 1994. The public sector shelved the idea because of resource constraints and the idea remained a distant dream for the people of Karnataka. The floodgates were thrown open to the private sector in 1990 to have a joint venture for integrated steel plant with KSIIDC but they withdrew due to infrastructure bottlenecks. In 1994, the Government of Karnataka approached the O. P. Jindal Group, which succeeded in starting Vijayanagar Steel Plant in a record of 33 months. The constraints were taken care of by adopting state of the art technology. Selecting the COREX process along with the traditional blast furnace route provided innovative solutions to power and water scarcity. Meanwhile road and rail linkage to Goa and Chennai were improved and the Government of Karnataka assured a steady water supply.JSW Steel has also formed a joint venture for setting up a steel plant in Georgia the Company has also tied up with JFE Steel Corp. Japan for manufacturing the high grade automotive steel. The Company has also acquired mining assets in Republic of Chile, United States and Mozambique.The first hot strip mill at Vijayanagar was commissioned in 1997. An important milestone was the commissioning of the Hot Strip Mill manufacturing Hot rolled Coil by backward integration in 1997. Since then it has grown exponentially and now it has an installed capacity to produce 10 MTPA (Mega tons per annum) of steel. Located at a remote village Toranagallu in the Bellary-Hospet area of Karnataka the heart of the high-grade iron ore belt and spread over 10,000 acres (40 km^2) of land. It is just 340 kilometres (210 mi) from Bangalore, and is well connected with both the Goa and Chennai Port. In 2005, JISCO and JVSL merged to form JSW Steel Ltd. It is the world's first Greenfield project in India and among the first in the world to have successfully used this technology to produce "green steel". It has the India's largest blast furnace with the capacity of 2.8 MTPA. This plant reuses 95% of the process wastes.

India's first 14 MTPA steel plant at single location, "**The fastest growing steel plant in India**". The JSW Steel Vijayanagar plant is the first integrated steel plant to reach 14 MTPA capacity in a single location. It is the first in India to use the Corex technology for hot metal production. Now other steel plants are implementing the same.

The Jindal organization was founded by the Late. Shri. O.P. Jindal ranked fourth amongst Indian business houses key industries including steel, power, oxygen, minerals and ports. Ranked as 6^{th} best integrated steel plant (for the year 2012) of the World by the World Steel Dynamics among 34 major steel industries on 23 parameters (which includes balance sheets, size, scale of operations, cost cutting efforts etc.). The group has achieved net profit of 13.34 billion and revenue of 485.27 billion in the Financial Year 2013 – 14.

2. BLAST FURNACE

Raw materials are continuously fed into the furnace top, producing the iron and slag which are removed at the base periodically. A hot air blast, together with auxiliary fuels, is injected into the furnace through the tuyers. it takes about eight hours for a piece of solid-feed material to pass through the furnace names of the various main parts of blast furnace are as shown in figure.

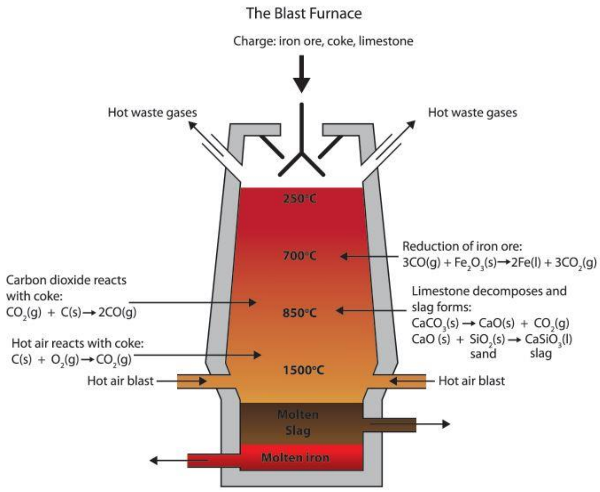

Fig.1: Blast Furnace

Coke reacts with oxygen and forms carbon dioxide

$C + O_2(g) \rightarrow CO_2(g)$

Limestone decomposes and forms another carbon dioxide

$CaCO_3 \rightarrow CO_2 (g) + Cao$

Carbon dioxide produced in the first 2 reactions reacts with excess coke and forms carbon monoxide

$CO_2 (g) + C \rightarrow 2CO (g)$

Carbon monoxide reduces iron ore and produces molten iron

$3CO (g) + Fe_2O_3 \rightarrow 2Fe + 3CO_2 (g)$

The excess limestone from the second reaction reacts with the sand (coming from minerals in iron ore) and forms calcium silicate (slag)

$Cao + Sio \rightarrow CaSiO_3$

Slag and molten iron are drained from the bottom of the furnace and gas produced exits through holes in the top of the furnace.

Fig.2 Blast furnace plant

3. SGP PLANT

Handling of blast furnace slag is an important aspect of modern blast furnace operation. Today, blast furnace slag is a saleable product (granulated slag sand for production of cement) rather than a difficult and costly waste material. It is the most popular and effective means of processing blast furnace slag in the world today. The process is highly flexible; and the compact sub-plant can be applied to any furnace configuration. Granulation, dewatering and storage of the slag can be done adjacent to the furnace or can be split up to suit available plant space or logistics. Handling of blast furnace slag is an important aspect of modern blast furnace operation. Today, blast furnace slag is a saleable product (granulated slag sand for production of cement) rather than a difficult and costly waste material. It is the most popular and effective means of processing blast furnace slag in the world today. The process is highly flexible; and the compact sub-plant can be applied to any furnace configuration. Granulation, dewatering and storage of the slag can be done adjacent to the furnace or can be split up to suit available plant space or logistics.

4. TYPES OF SLAG

After granulation of slag based on that appearance it was majorly divided into four groups.

a. **Sand type slag**: This type of slag having size 0.5 – 1 mm, easily separates from water because of its good settling tendency.

b. **Fine type slag**: This slag having very lower size < 0.1mm. It is always dissolved in water; Separation of this slag is difficult. It will separates only with settling of water in sumps for more time. Most in favorable because of lower tendency of settling it continuously rotates in the system. If we pump water having fine slag it completely spoils granulation. It causes wear and tear of pipes.

c. **Pop corn slag**: Very low density slag, floats on water. Impossible to separate with mechanical separators. Should separate only with over flowing of sump.

d. **Flake type slag**: low density flaky type and glassy phase separated only by filters most in favorable for SGP. It chokes the sump by forming scaffolds on the SGP inside walls.

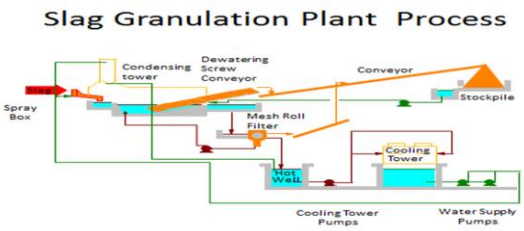

Fig.3: Slag Granulation Plant Process

The process of slag granulation involves pouring of molten slag through a high pressure water spray in a granulation head, which is located very close proximity to the blast furnace. Granulation process is controlled by quenching of the slag in cold water. This process does not allow time for crystalline growth to take place. Large volume of water is required (7 parts of water to 1 parts of molten slag being optimum). During the process of quenching, the molten slag undergoes accelerated cooling under controlled water flow condition and gets converted into glassy sand with 97% of the solid granulated slag particles less than 3mm and an average size of around 1mm. the impact point of the molten slag, the high pressure water jet is dependent on the slag flow, temperature, slope and shape of the runner.

SLAG GRANULATION PLANT CONTROLLING SYSTEM

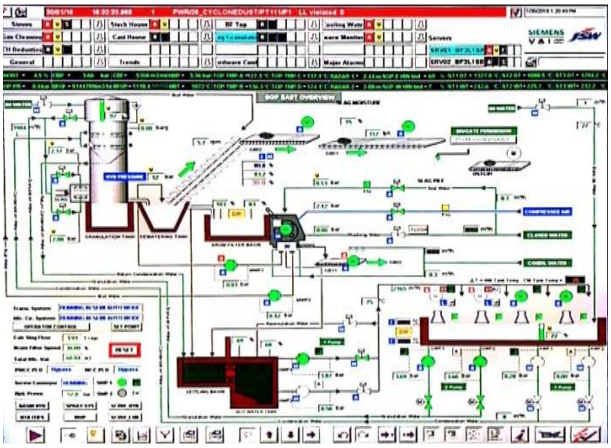

Fig.4: SLAG Granulation Plant Controlling System

SGP (Slag granulation plant)

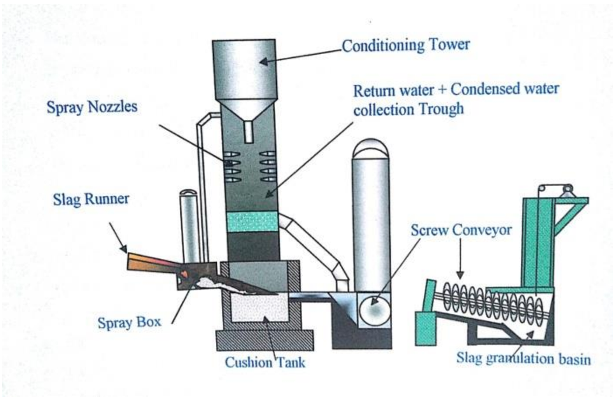

Fig.5: SGP

Hot slag is pouring in to the SGP from cast house runner spout; just below the spout cold water is pumped with high pressure nearly 2 Bar from blowing box. Slurry of both slag and water was formed. Because of high pressure slurry is flowing from slag tube to cushion tank, connecting channel to dewatering basin. There is screw conveyer to separate slag from slurry. All the coarser slag will be separated with screw conveyor. Remaining water is flowing through over flow channel reach drum filter basin. In the basin there ate baffle plates are stain less steel made to reduce water pressure of water so that lower the impact on RASA filter (Drum filter). Next water is passing from the filter all flaky type; some amount of fine slag was separated with 1mm mesh of this filter. A strong compressed head is used to separate slag from mesh. And slurry collected in the RASA filter chute was pumped back to drum filter basin with mud water pumps. Remaining water is going to settling basin where some amount of fine slag is settled. It can be cleaned with grab bucket in shut down. Then water enters to hot water tank, from there two hot water pumps are there to pump water to cooling tower. Water from cooling tower comes to cold water because of head difference. From cold sump two granulation pumps , two condensation pumps are pumping water to spray box and condensation tower respectively

5. EQUIPMENT'S IN SLAG GRANULATION PLANT

a. BLOWING BOX
b. CUSHION TANK
c. CONDENSATION TOWER
d. SCREW CONVEYOR
e. DRUM FILTER BASIN
f. RASA FILTER
g. SETTLING BASIN
h. HOT SUMP
i. COOLING TOWER
j. COLD SUMP
k. SLANG GRANULATION PUMP
l. CONDENSATION PUMP

COOLING TOWER

Fig.6**:** Cooling Tower

It is concrete tank this tank having four cells, each cell having capacity of 1450 m^3 capacity. Four tapings removed from hot water discharge main header normally called as raiser lines, all the lines are controlled by a manually operated butterfly valve, from their water reaches to distribution channel situated over cooling tower cell at an elevation of 25 meters, from there in different pipes, in different location of the pipes, water is falling through sprinklers to cool tower cell. In this process specific area of water increases then hot water lose its temperature to air, and then there is a significant reduction in the temperature of the water. Heat transfer α water volume in the system, should fill the cooling tower to maximum to reduce temperature. There are four fans situated above over flow channel, to reduce temperature.

OBSERVATIONS

General problems which are encountering in SGP plant

1. **Slag carry over in water**

After granulation in both tanks the slag slurry enters into dewatering wheel, the dewatering wheel helps to separate water and granulated slag. The dewatering wheel placed inside the Hooper and has 24 buckets and maintains grain size distribution of 95 % passing through mesh size 4 mm. after the granulation, granulated slag is discharged onto the conveyor. After dewatering of slag, the water comes through water flumes (channel) into settling basin. As per the design consideration the settling basin is mainly designed to settle the escaped slag from dewatering wheel, but as of now the rate of escaped slag is increased and hence settling basin have to be cleaned in every tap, which is not possible. The settling basin tank is 6m in depth and the overflow line is kept 2m from
the top. The settling basin tank fills with carryover slag and clarified water over flows to hot water sump, which is adjacent to settling basin. In hot water sump the water temp is around 95^oC and it contains fine granules slag particles. As the cooling tower is filled with carryover slag and sumps are getting overflowed. Such collected water at hot sump is re-circulated to spray header bypassing cooling tower. Due to presence of temp and slag particles in the quenching water affects granulation, properties of slag and as well as equipment, hence the frequent maintenance is being carried out where the equipment gets damaged. Presently the cooling tower is not working and by passed from the system in order to avoid the slag filling and hot water overflowing from the sump. These have leads to decrease in the efficiency of slag granulation plant.

2. **Wear and tear of pipes**

Collected water at hot sump is re-circulated to spray header bypassing cooling tower through the pipe line. Due to presence of temp and slag particles in the quenching water affects granulation, according to the properties of slag, the slag is corrosive element and it will have rough surface, when the slag water passing through the pipe lines because forced slag water, the slag rub the inner surface pipe lines, then the pipe lines wear and tear takes place and as well as equipment, hence the frequent maintenance is being carried out where the equipment gets damaged.

3. **Cooling tower efficiency is less**

Cooling tower is used to cool the granulated water which is collected in hot sump which is pumped by slag granulation pump through pipe lines to the common distribution channel from that channel sub distribution channel will be installed at varying distance to each other for distribution of water across the cross section area of water to the respective cell. As velocity decreases along with the length of the channel, slag settles in the channel, the slag accumulates in the channel and approx. 2/3 of the 15 m long channel gets blocked after a short period of time and water starts splashing across the walls of 1/3 of channel close to water inlet, leading to a poor cooling efficiency of the cooling tower.

Modifications in SGP Plant

1. **Increasing The Efficiency Of Cooling Tower**

Presently in blast furnace, slag granulation plant has having 2 cooling towers of approx. 1000 m^2 area each, for cooling of 3000 m^3/hr of water. each cooling tower consists of 4 cell is supplied by water through one pipe having a diameter of 500 mm, connected to a common distribution channel (length approx. 15000 mm) which is connected to 2x11 horizontal water distribution pipes (11 on each side) of diameter 150 mm (each pipe is perpendicular to the length of channel), installed at a varying distance to each other for distribution of water across the cross section area of the respective cell. As velocity decreases along with the length of channel, slag settles in the channel, the slag accumulates in the channel approx. 2/3 of the 15 m long channel gets blocked after a short period of time and water starts splashing across the walls of 1/3 of channel close to water inlet, leading to a poor cooling efficiency of the cooling tower. All channels will be presently cleaned at least once per month. Each diameter 150 mm horizontal water distribution pipe has 12 opening with a diameter of 75 mm to which were previously fixed diameter 65 mm pipes with 2 diameter 50 mm pipes with 2 spray nozzles with opening of 30 mm. spray nozzles were removed as they were choked with slag. Along the water distribution pipe, the water distribution is improper as velocity decreases along with length of the pipe and the last opening gets completely choked with the slag in a short period of time. There are presently three major problems, which are leading to improper distribution and to low efficiency of cooling tower, which are mentioned below and needs to be addressed to increase the efficiency of cooling tower and to reduce cleaning and maintenance work. In order to avoid settling of slag in the channel and to ensure uniform supply of distribution pipes with water, across the whole length of the channel and distribution of water inside the cell.

2. Solutions for The Problem

The following design modifications have been proposed to tackle the above the problems.

Adding concrete at the bottom of the channel between 4 water inlets (2 on each side) into diameter 150 mm water distribution pipes. The concrete should be placed with slope in the direction to the inlets of the water distribution pipes, to prevent settling slag. The height of added concrete at the middle point between 4 water inlets should be 200 mm. the bottom of the channel between to water inlets, adverse to each other should remain horizontal in a width of approx. 150 mm (diameter of water inlet pipe).Installation of a common strainer with a mesh of 10x10 mm for 2 water inlets adverse to each other. The strainer should have a roof from with distance at the bottom between two sidewalls of 500mm. height of strainer should be 350mm.Erection varying cross section pipe line above the channel with 11 gate valves of diameter 150mm for uniform distribution of water along the channel. The gate valves should be installed above the highest point of added concrete between water inlets.

3. Procedure for Erection of Water Distribution Pipe above The Channel

Concrete slabs placed above existing channel shall be removed. Bottom of the channel should be modified by addition of concrete as described above. A strainer with a wire mesh of 10 mm of square cross section as described above should placed between 2 openings for water distribution pipe 150mm diameter. One prototype gate valve diameter 150mm should be manufactured and checked for function and for eventual modification if required. A new circular opening of approx. 600 mm shall be made in the wall of cooling tower above the existing water inlet, for installation of diameter 500mm. its position will be given by the water distribution pipe, which should be installed with slope of approx. 3.3%(inlet part of the pipe approx. 500mm higher than the end of pipe).The water distribution pipe shall be fabricated in segments and welded on site. Eccentric reducers shall be used for connection of the segments o pipe with different diameter. The gate valve (in house made) shall be installed at the bottom of pipe and above the highest point of added concrete in order to achieve uniform distribution of water along the length of channel. The design of the valve is inverted circular cut of high radius at the front side of rectangular plate (refer flap drawing) to prevent water leakage between the plate and guide profile.

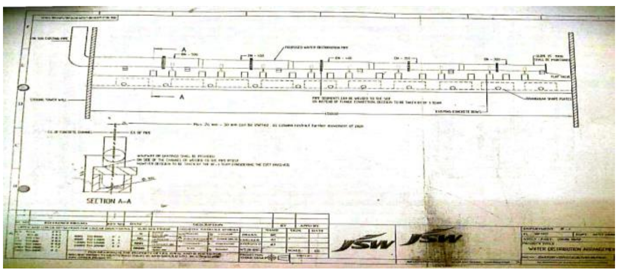

Fig.7: Design of Modified Model

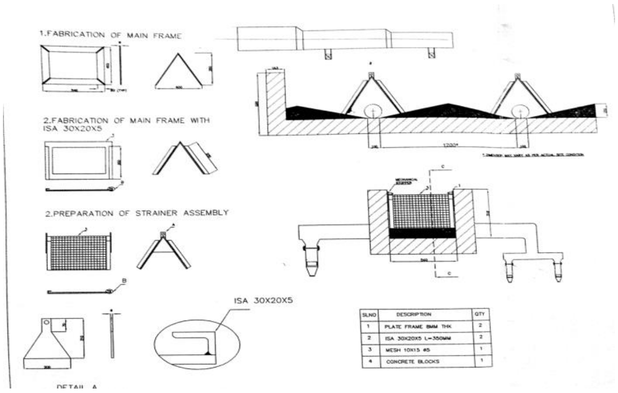

Fig.8**:** Mesh Manufacturingf

Fig.9: Final Mesh Product

6. RESULT FOUND BY IMPLEMENTING THE PROJECT

By implementation solution result will be obtained are as follows. Proper distribution of water along with the channel. The water is uniformly distributed throughout the cooling tower. The water temperature is reduced in cooling tower up to 8^0c-10^0c.This reduction of temperature will reduce the fine size of slag. And slag size will be increased. The increased size of slag will filtered in dewatering wheels. Because of reducing fine size slag, the water carry over in water is reduces and wear and tear of the pipe lines will be reduced. Also cooling tower efficiency is increased.

7. ESTIMATION OF COST

Si.no	Discription	unit	For one cell	Unit cost	Total cost
1	**ISA 30x20x5**	**MT**	**0.36**	**48000**	**17280**
2	**Mesh 10x5**	**Sq.m tr.**	**12**	**500**	**6000**
3	**Plate 5 mm**	**MT**	**0.48**	**28000**	**13440**
TOTAL COST (RUPEES)					**36720**

8. CONCLUSION

By the implementing the water distribution system in cooling tower it will reduces the water temperature. Because of the temperature difference the slag size will be increases this increased size slag will be filtered in the dewatering wheels. Hence the slag carry over in water is less. Wear and tear of pipe lines is reduced. The cooling tower efficiency is increased. By these above results the efficiency of the slag granulation plant will be increased.

Acknowledgment- We are thankful to M/s JSW steel Ltd for giving us this opportunity to carry out this project. We stand grateful to Mr. Nihar Patra (Dy.manager, Mechanical) for being our guide throughout the project. We remain grateful to Mr Shivanand Pompanna (AGM, Mechanical) who has constantly supported us with his appreciation. We also extend our gratitude to Mr.VSN Murthy (AVP, Maintenance, BF3&4) Mr.Vikash T (DPAO, BF3&4) who have extended their whole hearted support in project completion.

REFERENCES

[1]. Gupta S.S and Chatterjee A "blast furnace iron making" SAB publication.
[2]. Principle of iron making by A.K Biswas .
[3]. Tupkury R.H and Tupkury V.R., "An introduction to modern iron making", khanna publication.
[4].Taskanen P.A, Huttunen S.M., Mannila P.H and Harkki J.J., "Iron making and steel making", 29,2002,PP.281-286.
[5]. Noritaka Saito, Naoto hori, Kunihiko Nakashima and Katsumi mori, "Metallurgical and materials transactions", volume 34B, October 2003.
[6].D. S. Gathergood, "Coal Injection Into the Blast Furnace", International Iron & Steel Institute Committee on Technology, April 26, 1988.
[7].D. S. Gathergood and G. Cooper, "Blast Furnace Injection - Why Granular Coal"? Steel Technology International, 1988.
[8].Bethlehem Steel Corporation, "Comprehensive Report to Congress Clean Coal Technology Program - Blast Furnace Granulated Coal Injection System Demonstration Project", October 1990.
[9].D. Kwasnoski and L. L. Walter, "Blast Furnace Granular Coal Injection", Second Annual Clean Coal Technology Conference, Atlanta, GA, September 1993.
[10].D. Kwasnoski and L. L. Walter, "Blast Furnace Granular Coal Injection", Third Annual Clean Coal Technology Conference, Chicago, IL, September 1994.
[11].Bethlehem Steel Corporation, "Blast Furnace Granulated Coal Injection System Demonstration Project Public Design Report", March 1995
[12].L. L. Walter, R. W. Bouman and D. G. Hill, "Blast Furnace Granular Coal Injection", Fourth Annual Clean Coal Technology Conference, Denver, CO, September 1995.
[13].D. G. Hill, T. J. Strayer and R. W. Bouman, " An Update on Blast Furnace Granular Coal Injection", Fifth Annual Clean Coal Technology Conference, Tampa, FL, January 1997.
[14].D. G. Hill, T. J. Strayer and R. W. Bouman, "Blast Furnace Granular Coal Injection System Demonstration Project", Sixth Annual Clean Coal Technology Conference, Reno, Nevada, April 1998