ENERGY EFFICIENT CUPOLA FURNACE INTEGRATED WITH AIR POLLUTION CONTROL SYSTEM – A CASE STUDY

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Abstract

This paper presents case studies of successful demonstration units of energy efficient cupola furnace integrated with air pollution control device setup in the States of` Punjab, Haryana and Karnataka. The energy efficient cupola furnace includes the scientific design of Divided Blast Cupola (DBC), proper sizing of wind box, correct size and area of tuyers, optimum selection of blower specifications (volume and pressure), optimum well depth, size of wind belt etc. followed by a cost effective air pollution control device in the form of simple scrubber (wet cap). The design to the foundry units was provided by Punjab State Council for Science & Technology under an ongoing initiative of Department of Science & Technology (DST), Ministry of Environment and Forests (MoEF), Govt. of India which aims to provide energy efficient and environmental friendly technologies to small scale foundry units in India by setting up of the demonstration units. These units were operating successfully for more than 5 years. The investment for setting up of these units is at par with conventional cupola fabricated by the local fabricators. The scientifically designed furnaces have resulted in significant savings in fuel (coke) and energy. DBC has also helped to reduce rejection rate due to higher and consistent molten metal temperature delineated by the cupola. No power is required to run the Air Pollution Control System (APCS) except recirculation pump (2 HP). This air pollution control technology had already been replicated in more than 500 foundry units in the State of Punjab and demonstration units had been set up in the States of Haryana, Bihar, Karnataka, Jharkhand and J&K.

Background

There are over 6000 small scale foundries in India. Most of these foundries are concentrated in geographical clusters. The major clusters of cupola furnaces are located at Batala, Jalandhar, Howrah, Agra, Rajkot, Coimbatore, Kolhapur, Belgaum etc. The cupola is a hollow vertical, cylindrical shaft furnace used for efficient melting of pig iron, cast iron scrap and foundry returns to make cast iron castings. The castings are used in a variety of applications such as sanitary pipes and fittings, automotive applications and engineering components like casings for pumps, compressors and electric motors. The process is of batch type. An average cupola owner generally takes 3-6 heats in a month with heat time of 6-10 hrs/day.

The raw materials such as pig iron, cast iron scrap and foundry returns (rejected castings) are charged into the cupola furnace either manually or by mechanical charging. The hard coke is used as fuel. Most of the industries in India are using coke with ash content of 20-30%. But some of the enterprising units are using coke with low ash content of 10-12%. Limestone is added as a fluxing agent. Air is blown into the cupola through the tuyers.

Introduction

The demonstration units were set up at M/s Swastik Industries, Kaithal & M/s Bharat Iron Foundry, Smalkha in the State of Haryana and at M/s Bharat Iron and Steel Works in the cluster of Belgaum in the State of Karnataka. These foundry units are having molten capacity less than 3 T/hr with production of around 600-800 tons of casting per annum. Most of the foundries in these clusters have conventional cupolas (single blast) fabricated by the local fabricators with a very low efficiency (metal to coke ratio ranging from 5:1 to 8:1) and poor environmental performance. Some of the units have provided air pollution control devices in the form of side scrubbers to control the air pollution.

There is a significant scope for improving the energy performance in these conventional cupolas by upgrading to the energy efficient cupola furnace with cost effective air pollution control system.

Technology

The Divided Blast Cupola (DBC) is different from the conventional cupola technology in which the blast air is directed into the cupola through two separate rows of tuyers as against one in the conventional design. The two rows of tuyers are connected to two separate wind belts as against one wind belt in the conventional cupola design. The carbon monoxide being produced at the bottom tuyers is being brunt by the fresh oxygen from the upper row of tuyers. It improves the thermal efficiency of the cupola leading to less coke consumption and high melting rate. In divided blast cupola, the uniform metal temperature is maintained consistently at the spout. The bridging of the cupola is totally eliminated with longer duration of heat.

Divided Blast Cupola

The blower specifications are another area where the divided blast cupola is different from the conventional cupola. Most of the conventional cupolas deliver the requisite amount of air but they do not provide the desired pressure or vice-versa. The specifications for the divided blast cupola designed by PSCST ensure optimum blast volume and pressure to ensure proper penetration of combustion air into the coke bed. The optimum blast rate approximate fairly close to 375 ft ^{3}/min/ ft^2 (115 m^3/minute/m^2) of cupola X- section area. The wind pipe from blower delivery end to the wind box of cupola should have adequate diameter and minimum bends for smooth stream line of the blast air. There should be valve in the wind pipe for controlling the volume of blast air.

The tuyer area should be 15-20% of the total cross-sectional area of the cupola. In tuyers, a taper of 10^o shall be provided towards inside of cupola. This improves the coke bed temperature and avoids plugging of tuyers due to slag

½" gap between bricks & the shell is to be provided to take care of the expansion of bricks during heating & to prevent the occurrence of hot spots on the shell if metal penetrate the joints in the bricks work. IS 10 grade refractory bricks should be used in the cupola well. IS 8 bricks should be used in the combustion and melting zone. Cupola above the melting zone should be lined with IS 6 grade bricks. The optimum size of coke is 1/10th of the diameter of the cupola. With the use of low ash content coke, metal temperature improved by 25-50^{o}C along with reduction in coke consumption. The optimum initial bed height lies between 48" to 60" above the tuyers.

The major pollutants emitted by the cupola are SPM and SO_2. The PSCST has recommended low pressure scrubbing system in the form of wet cap, which is mounted on the top of extended stack to control air pollution. In this system, the natural draft of the hot gases is used to overcome the pressure drop. The efficiency of wet cap is around 70-80%. All the scrubbing effluent is recirculated without any discharge; rather fresh water is required to make up the evaporation losses. The capital cost of air pollution control system varies from Rs. 1.25 lacs to 1.75 lacs for a cupola having molten capacity less than 3T/hr. The recurring cost varies from Rs. 25-35 per ton of molten metal. The SPM after APCD was found to be well within the permissible limits i.e. 450 mg/Nm^3.

CASE STUDIES

S.No.	*Description*	*M/s Swastik Industries, Kaithal*	*M/s Bharat Iron Foundry Smalkha*	*M/s Bharat Iron & Steel Works, Belgaum*
1	***Product***	*Pump parts*	*Toka machine*	*CI pipes, Sluice valve*
2	***Production (T/annum)***	*540*	*1800*	*1200*
3	***Coke Metal ratio:***			
	Conventional Cupola	*1:7.89*	*1:9*	*1:12.5*
	Energy Efficient Cupola	*1:15*	*1:13*	*1:17.5*
4	***Coke Savings (%)***	*47*	*30*	*29*
5	***Coke Savings (T/annum)***	*32*	*62*	*27*
6	***Economic Gain (Rs. in lacs)***	***8.00***	***15.50***	***6.75***

Conclusion

The demonstration units reported above said savings on account of reduction in consumption of coke, lime stone and energy besides pollution control with pay back period of less than a year. Moreover, negative pressure is attained near the charging door thereby preventing the workers working on the charging platform for inhaling CO emissions. Further the quality of the sheds has also been improved due to the arrest of suspended particulate matter in the wet cap. The operation & maintenance cost of air pollution control system is negligible (Rs. 35/ton). The technology of wet cap was found to be very efficient for cupolas having melting capacity less than 3 ton/hr. The SPM after the wet cap was found to be well within the permissible limits i.e. 450 mg/Nm^3. Further, there is no bye-pass arrangement to bye pass the air pollution control system, whosoever is operating the cupola has to operate the air pollution control system.

Future Scope of Work

The instrumentation is missing in most of the foundry units in India. Every cupola should be equipped with minimum required instrumentation such as air pressure gauge, blast volume meter, bed height gauge, weighing scale, temperature gauge and any other basic instrument needed for the measurement of particular norm of the modification. All instruments must be calibrated as per standard procedure periodically.

Acknowledgement

The author wish to thank Ministry of Environment & Forests and Ministry of Science & Technology, Govt. of India for their continuing support to this initiative.