Savings from Divided Blast Cupola: A Case Study of Successful Implementation at a Foundry unit at Rajkot (Gujarat)

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Abstract

This paper presents a case study of successful implementation of Divided (Cold) Blast Cupola (DBC) at Shining Engineers and Founders, a progressive foundry unit located in Rajkot, in the state of Gujarat. After initial skepticism towards the new technology, the foundry unit decided to build a set of DBCs at a new site. Technical assistance, in terms of design and commissioning support, was provided to the foundry unit by TERI, under an ongoing initiative of SDC (the Swiss Agency for Development and Cooperation) which aims to provide energy-efficient and environment-friendly technologies to small-scale foundry units in India. A set of two DBCs were initially built by the foundry units, based on the designs provided by TERI. The first DBC was commissioned in August 2003 and has been operating for more than a year now. The investment in the new plant has proved to be financially attractive and has resulted in significant saving in coke at the foundry unit. DBC has also helped to reduce rejection rate, mainly on account of higher and more consistent molten metal temperature delivered by the cupola. Encouraged by the results obtained, the foundry has later converted its other cupolas to DBC design as well.

1. Background

Rajkot, in the state of Gujarat, is one of the largest foundry clusters in India. There are about 400 gray iron foundry units in Rajkot and they produce castings for a variety of industries such as diesel generator-set manufacturers, automobiles, textile machinery manufacturers, machine tools industry, pumps, valves and electric motors. The majority of the foundry units at Rajkot are small, and produce less than 100 tonnes of casting a month. Cupola is the main melting furnace employed by foundry units at Rajkot and a design of cupola, called ‘Rajkot Cupola’, is prevalent there. There is

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significant scope for improving the energy performance of these conventional cupolas operating in Rajkot by up-grading to the more efficient Divided (cold) Blast Cupola (DBC) operation.

TERI (The Energy and Resources Institute), with support of the SDC (Swiss Agency for Development and Cooperation), is promoting energy-efficiency and environmental improvement among small-scale foundry units in India. To showcase the benefits of the DBC to the Indian foundry industry, a demonstration plant was initially built at Bharat Engineering Works, a foundry unit located in Howrah in the state of West Bengal. The energy (coke) savings achieved in the demonstration plant was about 35% in comparison to the earlier cupola at the foundry unit. The demonstration also resulted in additional benefits, such as, higher metal tapping temperature, lower silicon and manganese losses and better carbon pick-up. TERI subsequently assisted other foundry units, located in West Bengal and Nagpur, to replicate the DBC and is presently working with a number of foundry units in Vijayawada, Coimbatore and Alwar.

As a part of the outreach effort to popularize the DBC technology in other foundry clusters in India, a workshop was organized at Rajkot, by TERI, in association with Rajkot Engineering Association (REA) in 2002. After initial skepticism on the relative benefits of the DBC expressed by the local foundry industry, one of the more progressive foundry units at Rajkot, Shining Engineers & Founders, decided to build a set of two DBC with technical assistance of TERI.

This paper outlines the successful implementation of the DBC at the foundry unit and the actual savings realized by implementation of the DBC.

2. Pre-commissioning audit

Audit of the existing cupola is an important activity for establishing the baseline energy performance of the cupola which are under operation in the plant. The pre-commissioning data, along with post-commissioning audit results, help in accurate quantification of the energy savings obtained by adoption of the DBC.

Pre-commissioning energy audit of the existing cupola at Shining was conducted in November 2002. The existing cupola had three rows of tuyeres and a diameter of 27 inches. The melting rate in the cupolas was 3.3 tph (tones per hour). A common bucket charging system feed the two cupolas. The furnace was continuously tapped into casting ladles.

A summary of the energy audit is provided below:

Charge coke consumption	:	9.1%
Ash in coke	:	11.4 %
Melt temperature at spout	:	1377 ^{o} C to 1528 ^{o} C
Temperature of flue gas (below charging door)	:	350 ^{o} C to 400 ^{o} C
Ferro-Silicon consumption	:	0.21 % of metallics
Ferro-Manganese consumption	:	0.13 % of metallics
Rejected castings	:	7 % (atleast)

3. Plant Specifications

Following the initial audit, a new cupola was designed for the foundry, taking into account existing cupola practice and the results of the audit. The foundry unit decided to build the divided blast (cold blast) cupolas (DBS) at a new site.

The specifications of the DBC were as follows:

No. of cupolas	:	Two
Desired melting rate	:	2.8 tph (tonne per hour)
Operation	:	Continuous
Desired metal temperature at spout	:	1425 ^{o}C to 1475 ^{o}C
Typical melting campaign duration	:	8 - 10 hours

It was decided to use a common mechanical charging system to feed the charge materials to the two cupolas.

4. Fabrication & Commissioning

Fabrication design drawings of the DBC was provided by TERI as per the broad design specifications finalized.

The melting zone diameter of the cupola was selected to be 610 mm or 24 inches. The cupola was of M.S. (mild steel) fabrication with two rows of tuyeres and drop bottom doors. The cupola shell was made of 10 mm M.S. plate, while the windbelt and blast mains were fabricated of 6 mm plates. The base plate was of M.S. of 40 mm thickness. Each of the two wind-belts had four tuyere elbow fitted with butterfly control valves, extension pieces through the refractory and inspection covers incorporating site glasses. All the tuyeres and elbows were made of cast iron.

The blower fan fed a single blast main which subsequently bifurcated to feed the two cupola wind belts. The two blast mains are equipped with necessary values /dampers for controlling the proportion of the blast going to each row of tuyeres. TERI specified the capacity and discharge pressure of the blowing fan and provided a list of reliable fan manufacturers in India to the foundry unit.

The cupola structure was designed to be free-standing. Access stairways were provided at different levels of the cupola for ease of maintenance and inspection. The refractory brick lining of the cupola was done as per existing local practices, and under guidelines provided by TERI (see Box 1).

Box 1: General guidelines for cupola brick lining

1. Use of IS-8 grade bricks or any good quality 40% alumina bricks especially in the melting zone of the cupola.
2. Fireclay (whitish in colour) should be used for joining the bricks.
3. Soak the fireclay for 7 days before use.
4. Leave ½ inch gap between the cupola shell and brick layer and fill this with sand used for moulding.
5. Minimum quantity of fireclay is to be used to join the bricks. Ensure that the bricks are laid as closely together as possible, because open joints are vulnerable to slag attack.
6. The new lining should be pre-heated slowly (alteast 3-4 times) about a week before commissioning. A slow fire should be maintained in the cupola. For preheating the cupola, put some dry sand on the bottom, followed by firewood and coke in 2-3 installments to a height of 1 m above the top tuyeres. Leave the ignited coke bed overnight. The launder may be heated by burning firewood on it. It is inevitable that some cracks will appear during pre-heating and these should be patched before the first melt.
7. It is advisable to give a coat (20 / 25 mm thick) of ganister over the newly lined bricks.
8. The first trial melt should be of short duration, say 2 hours. After the melt a ganister patch should be applied in the normal manner.

Note:
Burn – back during the first melt in a newly bricked cupola is generally considerably heavier than during normal operation. It is not, however, necessary to re-brick the cupola but conventional patching should be applied and then dried out slowly.

Advisory support during the fabrication and installation of the DBC was provided by TERI. The first DBC was commissioned in August 2003. TERI team was stationed at Rajkot till the DBC was stabilized and satisfactory performance was achieved. Better operating practices (see Box 2) were discussed and demonstrated to the cupola operators and plant supervisors during the commissioning trials.

Box 2: Sample Operating Procedure for TERI's divided blast cupola

A. *Coke bed preparation*

1. Place the required firewood on the sand-bed.
2. Add the first installment of bed coke (1/4th of total bed-coke weight). Only selected size of coke to be used in the bed.
3. All lower tuyere covers should be open and the tuyere valves should be closed at the time of ignition of the bed.
4. Observe the ignition of the first installment of coke and add second installment when the ignition is found to be satisfactory.
5. Similarly, observe the ignition and put in the third installment.
6. Keeping the fettling door open, close the lower tuyere covers and blow-off for about 30 seconds.
7. After blow-off, ensure there is no hanging of coke in the bed. If any hanging is observed, poke through the tuyeres to consolidate bed.
8. Close the fettling door, add the fourth installment of bed coke and check the final bed height with gauge.

B. *Charging and cupola operation*

1. Charge the bed limestone and start charging immediately.
2. Avoid charging large pieces of metallics.
3. When the stack is full, close the tuyere covers and open all upper and lower tuyere valves.
4. Start blower.
5. The stack should always be full during the melting. If for any reason this is not the case, the blower should be shut off and the condition rectified.
6. Whenever the blower is switched off, all the turyere covers should be opened and tuyere valves closed.
7. The tuyeres must be kept clear at all times. This requires constant attention by the cupola operators.
8. If it becomes apparent that the bed height is being burnt away (e.g. blast being turned off) or if conditions in the cupola become excessively oxidizing then a coke/limestone booster should be added.

C. *Plant shut down procedure*

1. After last charge is added and stack is blowing down, reduce blast flow to top tuyeres and increase flow to bottom tuyeres.
2. On tapping last metal, turn off the blower.
3. Open emergency tap hole on siphon box and drain.
4. Open all tuyeres.
5. Remove props and open bottom drop doors (warning: make sure no water is in the drop area).
6. Drop bottom and check that coke bed has been cleared from tuyeres and that there is no slag inside the tuyeres.

5. Post-commissioning audit

Three trial runs were taken in the DBC in order to fine-tune the operating parameters. Though some of the operating practices of DBC were new to the operators, the better results obtained in the DBC probably inspired them to inculcate the new operating procedures being advocated to them.

The result of the post-commissioning energy audit conducted during the third trial melt runs, is summarized below:

Charge coke consumption	:	7.8 %
Ash in coke	:	12.2 %
Melt temperature at spout	:	1417 ^{o} C to 1462 ^{o} C
Temperature of flue gas (below charging door)	:	132 ^{o} C to 162 ^{o} C
Ferro-Silicon consumption	:	Nil
Ferro-Manganese consumption	:	Nil
Rejections	:	about 5%

6. Cost Savings

On the basis of the pre-commissioning and the post-commissioning audit results, the savings from implementation of the DBC were worked out. Table 1 summarises the total savings obtained from reduced consumption of coke and other materials as well as reduction in rejection levels.

Table 1 Actual cost savings per tonne of melt output

	Consumption before, % of metallics charged	Con-sumption after, % of metallics charged	Savings after implement-ation of DBC	Approx. unit cost at Rajkot (Rs/tonne)	Monetary savings Rs/tonne of molten metal
A. Savings in materials + energy					
Coke usage	9.1%	7.8%	30%	18,000	234
Ferro-silicon	0.21%	Nil	100%	63,000	132
Ferro- manganese	0.13%	Nil	100%	60,000	78
Total (material + energy)					444
Less: Additional power consumption in blower					(26)
Net savings (material + energy)					418
B. Reduced rejects					
Savings per 1% reduction in rejects					225
Reject levels: before 7%, after 5%					
Total savings (2% reduction in rejects)					450
C. Total cost savings (A+B)					**868**

Hence, there was a savings of the order of Rs 850 per tonne of molten metal in the foundry unit. For a typical foundry unit, melting about 250 tonnes of metal a month, the total savings translates to about Rs 2.2 lakhs per month. The capital cost of a DBC, inclusive of civil work, platforms, bucket charging system etc, is about Rs 10,00,000. It is also possible to retrofit a conventional cupola to DBC, by simply changing the blower and blast arrangement. The capital cost of the retrofit option is about Rs 2,00,000. The capital investment, even in a new DBC, usually pays back within a year, depending on the amount of metal melted in the foundry unit.

7. Conclusion

Encouraged by the success of the DBC, Shining has converted their other cupolas to divided blast operation as well. The results obtained in Shining also show that there is a huge potential for energy saving and GHG (Green-House Gas) reduction in conventional cupolas being operated by other foundry units operating in the small-scale sector in India. TERI is willing to extend technical support to any other foundry unit who may be interested to upgrade their cupola plant and make it more energy efficient.

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