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"Relevance of Using Cupola Furnace in Current Scenario of Technological Advancements."

Huzaifa Fidvi[1], Dr. Akash Langde[2]

[1]Asst. Professor, Mechanical Engg. Department, Anjuman College of Engg. & Technology, Sadar, Nagpur, Maharashtra, India

[2]Prof. & Head, Mechanical Engg. Department, Anjuman College of Engg. & Technology, Sadar, Nagpur, Maharashtra, India

ABSTRACT

The present study is done to ascertain the relevance of using old conventional cupola furnace in these modern times of technological advancements. Despite the fact of the big development of the technology of melting cast iron in electrical furnaces, an essential part of melting cast iron especially in Indian SME context is still done in cupolas. Various technical papers are reviewed. Conclusions are drawn from these findings to know the need and importance of using Cupola Furnace for melting Cast Iron in the present era of technological advancements.

Keywords: Cupola, Electric Arc Furnace, Electric Induction Furnace, Duplexing, DBC, CCR, PCD.

I. INTRODUCTION

A foundry is a factory that produces metal castings. Metals are cast into shapes by melting them into a liquid, pouring the metal in a mould, and removing the mould material or casting after the metal has solidified as it cools.

The foundry industry manufacturers metal cast components for applications in Auto, Tractor, Railways, Machine tools, Defence, Aero, Earth Moving / Textile / Cement / Electrical / Power machinery / Pumps / Valves / Textile Machinery, Sanitary pipes & Fittings & Castings for special applications etc.

FOUNDRY

- **GLOBAL SCENARIO**

As per recent figures the global market of metal castings is estimated to be about **USD 30 billion** (Choudhary and Jain [(1)]).

- **INDIAN CONTEXT**

India is acknowledged as the **world's second largest** producer of castings producing 7.4 million tons per annum approximately valued at **USD 8 billion** with Exports approx. **USD 2 billions (Rs.12000 Cr).**

Indian Foundry Industry Scenario

Approx Units : 4600
Major Clusters: 19
Production : 9 Million MTPA
Employment : 5,00,000 Directly
15,00,000 Indirect
Productivity per Unit: 1950 MTPA
Avg. Productivity/Man/PA: 20

Max Productivity: 90

Location of Major Clusters

Each Cluster is known by the industrial products it is serving.

4600 Foundry Units are grouped in 19 Clusters

Table 1

Major Clusters	Famous For
Coimbatore	Pump-sets, Textile M/c castings
Kolhapur & Belgaum	Automotive castings
Rajkot	Diesel engine castings
Howrah	Sanitary castings
Batala, Jalandhar, Ludhiana	Machine Tools
Agra	Sanitary castings
Chennai	Electric Motor castings

Distribution of Foundries Sector wise:-

- 80% Units are in Small Scale Sector – Manual Labour Based
- 10 % Units are in Medium Scale Sector – Semi Mechanized
- 10 % Units are in Large Scale Sector – Mechanized and Some Are World Class

Various types of Furnaces used for melting metal to make Grey Cast Iron Castings are:

- Cupola
- Air furnace
- Rotary furnace
- Electric furnace.
  - Arc furnace
  - High frequency induction furnace

Furnace choice is dependent on the alloy system required, quantities produced. For ferrous materials Electric Arc and Induction Furnaces, Cupolas are commonly used. Air Furnace and Rotary furnace are small capacity furnaces and are used in tiny sector enterprises.

II. LITERATURE REVIEW

Literature review is done to ascertain the relevance of still using cupola furnace in these times of technological advances.

1. Bharati Vidyapeeths College of Engineering (BVP), New Delhi [2] notes discusses on the various furnaces used for melting. On 'Cupola furnace' it says that it is a very old method developed in early 1900's. For many years, the cupola was the primary method of melting used in iron foundries.

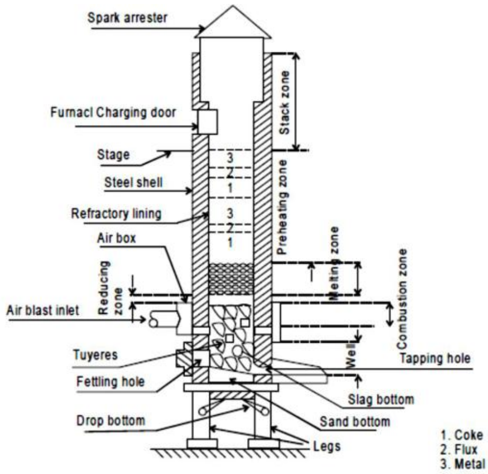

Figure 1. Typical Cupola Furnace

It has several unique characteristics which have made it popular for its widespread use as a melting unit for cast iron. (a) cupola is a tubular furnace which produces cast iron by melting scrap and alloys, the heat energy source being the energy generated from the combustion of coke (a coal derivative). (b) Continuous flow of molten iron emerges from the tap hole at the bottom. (c) Flow rates can be as high as 100 tonnes per hour. (d) As the metal melts, it is refined partially which removes contaminants, enabling use of dirty charges which is not possible in electric furnace.

Advantages listed of Cupola Furnace are:

- It is simple and economical to operate.
- Wide range of materials steel and iron without reducing melt quality are accepted.

- Dirty, oily scrap can be melted as well thereby playing an important role in the metal recycling industry.
- Cupolas can refine the metal charge, removing impurities out as slag.
- From a life-cycle perspective, cupolas are more efficient and less harmful to the environment than electric furnaces. This is because they derive energy directly from coke rather than from electricity that first has to be generated.
- The continuous rather than batch process suits the demands of a repetition foundry.
- It has high melt rates.
- Less floor space required compared with other furnaces of same capacity.

Limitations

- During melting, certain elements like Si, Mn are lost while others like sulphur are picked up. This changes the final analysis of molten metal.
- Close chemical composition and temperature control is difficult to maintain.

The paper summarizes that Cupola is a furnace used for melting steel scrap, cast iron scrap, and ferroalloys to produce cast iron. It is one of the oldest methods of producing cast iron, and it remains the dominant method because of its simplicity and low fuel cost the energy source being coke (coal derivative).

2. In technical paper [3], the author conducted a questionnaire based study among the foundries in Coimbatore area and noted that in mid twentieth century laws stipulating maximum level of pollutants were promulgated making the foundries install energy efficient electrical melting technologies & PCDs (Pollution Control Devices) especially induction furnace.

While stating the benefits of conventional cold blast cupola as lower cost of installation but it had too much dependence on skill and judgement of operator. The author noted that induction furnace being clean, energy efficient and well controlled melting process are replacing cupolas with their disadvantage being high initial cost and that only high quality metals can be melted.

Later Government of India imposed severe restrictions on power consumption, load shedding time limits forcing foundries to cut production. They were able to meet only 60% of their demand, compelling them to turn back to coke based cupolas while meeting environmental norms.

3. Michaela Boehm[4] in his comparative study between state-of-the-art cupola and medium frequency coreless induction melting compared them on factors such as energy costs, environmental regulations, charge materials, labour and production levels. Underlying these factors is one cost unit--dollars per ton of molten iron. All factors are quantified in dollars per ton of molten iron and then totalled to determine the cost-effective melt solution.
   Cost analysis of a 40 ton/hr cupola and a 40 ton/hr medium-frequency coreless induction melt system. The systems being analyzed are for Greenfield installation and 4000 hr/yr of operation. For this analysis, the melt systems are for a Midwest U.S. foundry that requires base iron for ductile iron and will melt 16 hr/day, five days a week.

III. MELT SYSTEM COST COMPARISON

(Dollars ($)/ton of iron melted)

Table 2

Cost Head	Cupola $/ton	Induction Furnace $/ton
Metallic Charge	135.44	151.73
Additive	9.29	12.98

Materials		
Melt Energy & Utilities	23.42	29.58
Labour	3.98	4.52
Refractory / Labour	1.76	3.07
Waste	1.48	0.51
Disposal		
Maintenance	6.40	4.40
Buildings and Other	10	10
Total	**191.77**	**216.79**

Total Cost Difference between cupola and medium frequency induction furnace is **$25.02/ton** of iron melted. Capital Investment is 25 % less for medium frequency induction furnace while Break Even level is 67000 tons annually for cupola and 165000 tons annually for induction furnace.

The cost per ton of iron melted is less for cupola and it has a lower break even point though with higher capital investment.

4. Dr. V. P. Gupta [5] in his study compared cupola which has a image in India as a dirty, polluting and energy inefficient melting method of small, foreman operated cast iron foundries producing non graded, poor quality general engineering castings with modern induction furnaces.

He also noted that India is the 2nd largest producer of castings in the world and that 35% of C.I. Castings are produced by traditional conventional cupolas. Developments like hot blast, oxygen enrichment of blast, oxy-fuel injections etc. were not found suitable for Indian conditions whereas Divided Blast Cupola (DBC) was found favourable. The most striking and surprising findings are the very poor thermal efficiency of (25%) and very high carbon print (1450 Kg CO2 per ton) of induction furnace against 60% thermal efficiency and 350 Kg CO2 per ton for Divided Blast Cupola. (This is because theoretically based on Carnot cycle, thermal efficiency cannot be more than 39% for converting thermal energy to mechanical power and then to electricity in thermal power plants which gives a final efficiency of 25% considering 60-65% efficiency of the furnace itself). In case of cupola melting the charge comes directly in contact with the hot gasses and heat transfer to melt the charge, thus giving a higher thermal efficiency of 60%.

Direct comparison of carbon foot print of large scale foundry operations using cupola or induction furnace is 1.16 & 2.86 tons of CO_2 produced per ton of castings respectively. Induction melting foundry produces more than two and a half times C02 than a cupola foundry for same production.

‘Therefore we should not hesitate in saying that cupola melting is far far better than induction furnace from both points of views, energy conservation and global warming’(5) In fact the cupola is contributing to more than 70% of world CI/SG production.

Carbon Credits: The carbon foot print reduction should give carbon credit benefit under the CDM (clean development mechanism) of UNFCC to the foundries. A foundry of 1000 tons /month can think of getting CRR’s worth Rs.30 lacs annually for using DBC/ cokeless cupola in place of Induction Furnaces.

“These induction furnaces became popular decades back when dirt cheap stainless scrap disappeared from the western markets and these furnaces switched over to steel production of second quality for mini rolling mills etc and multiplied in numbers to include CI melting. And our casting users mistakenly degraded the cupola to poor old dirty technology incapable of producing automobile quality castings. The times have changed but we have not moved with time in this regard".

The author in his conclusion ranked melting furnaces in Indian context as:

Table 3

Rank	Furnace	Energy Efficiency	Economy Rs./ton	Eco Friendly kg CO_2/ton
1st	D.B.Cupola	55-58%	1800-1900	300
2nd	Duplexing (combination of DBC + Induction Furnace)	80-90%	3000-3400	180
3rd	Induction Furnace	25%	3200	1450

He suggested that Small foundries must modify/replace their cupolas to DBC and start duplexing in small induction furnaces to improve quality and reduce rejections to save further cost. Medium scale foundries being set up should install requisite numbers of cupolas with induction for duplexing. Large foundries must expand by installing requisite number of cupolas to duplex in existing induction furnaces.

IV. CONCLUSION

On the basis of this research we can conclude that, Cupola is the oldest and primary method for melting of Cast Iron but with the introduction of induction furnace and it being clean, energy efficient and well controlled melting process replaced cupolas. On imposition of severe restrictions on power consumption, load shedding time limits forced foundries to turn back to coke based cupolas while meeting environmental norms. In the current scenario duplex foundries are preferred where the melting is done in Cupola Furnaces and then the molten metal is duplexed in a induction furnace for cleaner melting, ease of composition control, improving quality and reducing rejections. Finally we articulate that Cupolas have found favour again and have become indispensible in modern foundries. Today, India is the 2nd largest producer of castings in the world and that 35% of C.I. Castings are produced by traditional conventional cupolas.

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