Assessment of the Economics of Cokeless Melting in India

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History

The Cupola was developed at Hayes Shell Cast in England in the late 1960`s and the first production cupola started in December 1970. There was a lot of interest in the process as coke was eliminated, there was no sulphur pick up when using natural gas, propane or kerosene plus there was no visible emission when the cupola was operating. However this was not enough and while foundrymen were very impressed they asked " how much cheaper is it to melt?"

The technical advantages always created the interest but there must be an economic advantage before a foundry would buy the cupola. Early installations were made in the Middle East where the cheap gas and oil replaced expensive imported coke so that the cokeless cupola was very much cheaper and made a good investment.

The cupola as adopted in Mexico where pollution concerns were forcing foundries to close so that the cokeless cupola enabled them to meet the environmental requirements and stay open. A considerable saving in cost as well as jobs.

In Europe in the early 1980`s good quality coke was still available at reasonable cost but pollution regulations had become more strict so a bag filter was required even on a cokeless cupola to meet the low level of solids demanded. Additionally all of the larger cupolas used continuous tapping and required temperatures above 1500 deg C to feed metal to automatic moulding lines. This could not be economically achieved from the cokeless cupola. Eliminating coke still had advantages particularly for ductile iron production as well as giving better control of quality, hence duplexing was adopted. A cupola is a very efficient melting unit and an electric furnace is very efficient at superheating. By combining the two furnaces in the duplex process the required temperatures could be achieved and good cost savings were possible. Duplexing was adopted by several foundries in Europe as well as Japan and latter in South Korea. More recently it has been adopted in India.

Design

It is important to understand the design of the cokeless cupola so that the cost of the various items that affect the economics can be appreciated. Figure 1 is a diagrammatic arrangement of the cupola. The three most important features that influence the cost are the fuel, the spheres and the carbon injection. The fuel can be natural gas, propane or oil although in India natural gas is the cheapest so all the cupolas installed so far have used natural gas. The amount of gas consumed will depend on the tapping temperature as will be seen later. The spheres are the most important part of the design. The bed of spheres act like a heat exchanger. The metal melts above the spheres and as it flows over the spheres and down through the bed it is superheated, hence the deeper the bed the higher the tapping temperature. Consumption of the spheres increase as the temperature increases and this is not a linear relationship. There is a practical limit on the tapping temperature above which the sphere consumption becomes uneconomical. Finally some carbon is lost during melting so carbon needs to be added particularly if the charged carbon is lower than is required in the tapped iron. The grading of the recarburiser is important as fine material burns as it is blown into the cupola. The ideal grading would 0.5 – 3 mm with no fines. The carbon recovery can be as high as 60% with the right grade of graphite and a high tapping temperature. It can be down to 30% at lower temperatures and cheaper recarburiser

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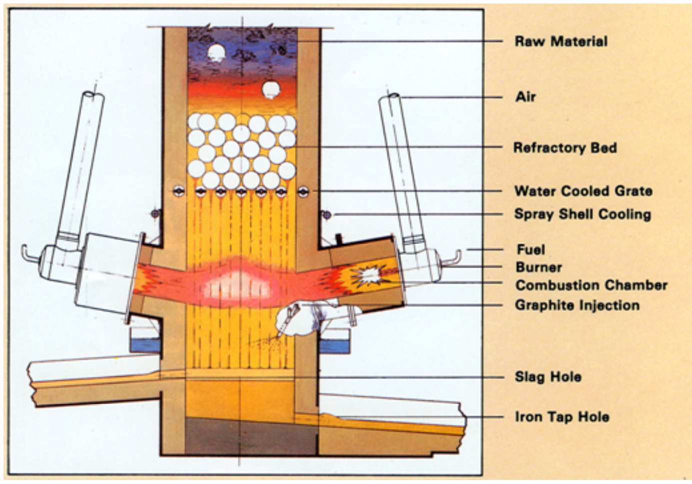

Figure 1

Technical Cost Advantages

Eliminating coke means there is no sulphur pick up during melting particularly when using natural gas so the cokeless cupola makes an ideal melting furnace for the production of base iron suitable for treatment to make ductile iron. There is also some saving by not having to store and handle large volumes of coke plus less money tied up in stock.
Desulphurising iron costs money and the metal has to be superheated after desulphurising prior to converting to ductile iron. Also the slag formed has to be removed from the ladle and disposed. By adopting the cokeless cupola all these are saved.

Eliminating coke means the main source of pollution has been removed. There is growing pressure to reduce emission and cupolas are particularly vulnerable as they are so visible with the exhaust of the cupola usually well above the building line. There is always visible emission when a coke cupola is operating making it very easy to see compared with no visible emission with the cokeless. People are less likely to complain when they cannot see anything. Although the current Indian regulations are not too strict and a simple wet arrester is often sufficient, this will not continue and pollution control can be very expensive in both capital and running cost. Figure 2 shows the cupola at Anil Metal working and no visible emission.

Figure 2

There is less lining wear in the cokeless cupola particularly when it is used in the duplex process. Longer campaigns are possible and with water-cooling of the shell the cupola will run for two days none stop even with the conventional brick lining.

The price of coke has varied considerably and particularly good quality imported coke has increased dramatically. The price is controlled by world market demand and with much of the coke coming from China, the Indian foundry industry has little influence. When adopting the cokeless cupola the gas is available in India so there is less fluctuation in price. Most important is that the spheres are manufactured in India.

When the process going to be introduced in India it was decided that the spheres must be made locally. A lot of investigation was carried out and materials tested in England to ensure they were of the correct quality. Spheres were then manufactured on a new plant in India and routine tests showed they met the same standard as those made in England. Spheres were then taken to the British Ceramic Research Association and fully tested which showed they were of the same quality as was produced on the sphere plant in England had been used around the world. When adopting the cokeless cupola the foundry can be satisfied that there is a secure supply of this critical material in India.

Cupola Operation

One way to use the cokeless cupola is as a unit melter when high temperature metal of the correct composition is tapped directly from it. The maximum temperature is obtained by coating the bars that support the bed with refractory to insulate them and reduce the loss of heat to the water. A bed of spheres around 600 – 700 mm deep is used to give the greatest superheat. Any further increase in depth has no effect and reduces the melting rate as well as increasing the consumption of spheres. Tapping temperatures of around 1450 deg C can be obtained under these conditions. Oxygen enrichment of the air can be used to further increase tapping temperature and a 2% addition increases the tapping temperature by about 30 deg C. However at these temperatures approaching 1500 deg C the sphere consumption will rise to about 3 % with gas consumption 85 – 90 cu m / tonne. This may not be economical except in special circumstances.

At 1450 deg C sphere consumption is around 2.5 % and gas consumption 80 – 85 cu m / tonne. The carbon injector has a rotary valve and the speed can be simply changed at the control panel. The tapped carbon can be easily adjusted by controlling the injection rate so much more consistent analysis can be obtained. The carbon content needs to be checked by taking regular CEV samples and adjusting the injection rate as necessary. The cost of recarburising will vary considerably depending on charge make up, amount of steel being used, whether grey or ductile iron is being produced and finally on the tapping temperature.

The refractory coating of the bars lasts for 250 – 300 tonnes of metal melted and then the bars have to be replaced and the old bars recoated. This is done by the foundry as a simple casting technique is involved. With uncoated bars the tapping temperature is about 30 deg C lower and this may be sufficient for many castings. With uncoated bars there is no need to change them and they can be used for many months. There is a small cost saving with uncoated bars.

The second way to use the cokeless cupola is in a duplex process when the cupola is used as a prime melter and the iron transferred to an electric furnace for superheating, recarburising plus any other modification to the analysis of the iron. This is the most economical way to use the cokeless cupola but does involve extra capital expenditure with the installation of an electric furnace. However if a foundry already has an electric furnace and wants to increase capacity installing a cokeless cupola could be much more economical than installing additional electric furnaces.

When duplexing, metal is tapped from the cupola at the lowest practical temperature to keep the sphere and gas consumption to a minimum. The bars are not coated so they do not need changing for many months and the shell is usually water cooled so longer campaigns are possible. At around 1300 deg C sphere consumption would be 1.25 – 1.5 % and gas 55 – 60 cu m / tonne. Liquid iron only requires 38 kwh / tonne to superheat through 100 deg C so as only a relatively small amount of power is required the cost is low. This means the duplex process is very economical. Additionally lining wear is less at the lower temperature so longer campaigns are possible. The electric furnace means the foundry can control the composition very closely and also obtain whatever temperature they need.

The operation of the cokeless cupola is very easy and the preparation of the cupola is very similar to a conventional cupola. The outlet of the burners needs attention similar to the tuyeres. Some repair may be necessary around the bars and then the bed of spheres is put on similar to the coke bed except it is done when the cupola is cold. After preparing the bottom and back door in the normal way the cupola is ready for operation. It is essential for good operation of the cokeless cupola that the air / gas ratio is maintained under all conditions. Certain safety requirements when operating with natural gas also have to be met. The main control panel, shown in figure 3, meets all these requirements. A plc controls all the operation but this is very easy to operate. The design has been made very “ user friendly ” so that the operator simply selects a switch and the panel does the rest. After lighting the burners a second position of the switch is selected for preheating and then a final position for melting. Shutting the cupola off is also straightforward.

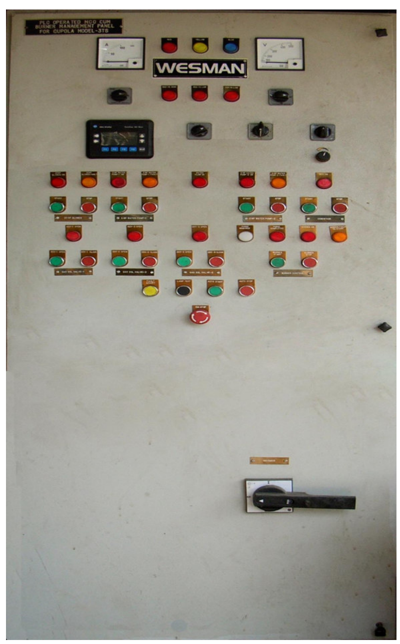

Figure 3

Practical Experience

Vishal Malleables Ltd of Ankleshwar produce ductile iron only and were using coke cupolas to provide the liquid metal. This was tapped into a ladle for desulphurising and after de-slagging the metal was transferred to electric furnaces for superheating and modifying the analysis. After they saw the success of the first installation at Anil Metal in Agra they decided to adopt the cokeless cupola and as they had existing electric furnaces they would use the duplex method.

They continued to operate their coke cupolas while a new cokeless cupola was built alongside which would use natural gas. This cupola was rated at 4 tonnes per hour and 3 burners were installed around the shell, similar to Anil Metal but with a larger diameter shell. The cupola was designed to have uncoated bars and a water-cooled shell was also included. A new charging system was built using a drop bottom type bucket to ensure even distribution of the charge. Commissioning started in September 2007 and within a few melts it was run for 24 hours. Figure 4 shows this first installation during tapping. The metal was transferred directly to the electric furnaces by ladle as no desulphurising was necessary and the metal superheated and the analysis adjusted as before. The success of this first cupola encouraged Vishal to go straight ahead with the second cupola and they have been operating solely with the cokeless cupola for over one year.

Figure 4

The charge was 500 Kg and the make up was 40 % pig iron and 60 % foundry returns plus 2 % dolomite (dolomitic limestone). Spheres were also added with the charge. The charged carbon was 4.0 % and silicon 2 %. During melting there was an approx loss of 10 % so the tapped carbon was 3.5 % and silicon 1.8 %.

Gas consumption over this period has varied between 50 and 60 cu m / tonne. Metal temperature was measured at the end of the launder and was around 1330 deg C which means the tapping temperature was at least 1350 – 1360 deg C The sphere consumption was around 2 % which includes slow running plus breaks when the shift is changed. The electric consumption was very similar to the previous coke operation as metal was transferred to the electric furnaces at similar temperatures. Carbon addition in the electric furnace was also similar.

Table 1 below shows the comparison at today's prices between the previous coke operation when the overall coke consumption was 12 % and the current cokelss operation.

MELTING COST PER MT

MELTING COST PER MT AT VISHAL MALLEABLES	
COKE CUPOLA	
Coke - 12% @ Rs 24000 per MT	**: Rs. 2880**
COKELESS CUPOLA	
Natural Gas 55 CuM @ Rs.18/- / CUM	: Rs. 990
Spheres 2.0% @ Rs 29000 per MT	: Rs. 580
TOTAL	: **Rs. 1570**
SAVING Rs. 1310 per MT	

Table 1

This is a very good saving. The price of coke has been as high as Rs. 36,000 per MT and even if it goes down to Rs. 16,000 per MT there will still be a saving of nearly Rs. 350 per tonne of metal melted. Additionally there is the saving of no desulphurisation or disposal of slag to be considered.

Conclusion

The cokeless cupola completely eliminates the use of coke. This gives a number of cost advantages. It removes the reliance of the Indian market on the import of good quality coke, which has varied considerably in price and is now expensive plus the supply in the future is doubtful. Eliminating coke removes the main source of pollution which can be costly to reduce and regulations will only get more strict. As there is no coke in the cokeless cupola there is no sulphur pick up so the cost of desulphurising is removed making the cokeless cupola an ideal unit for the production of ductile iron.

Coke is replaced by a fuel with natural gas being the cheapest option and is becoming widely available in India so future supplies will not be a problem. Propane and oil are also options and both are readily available. There are also the ceramic spheres, which act as a heat exchanger in the bed. As these are manufactured in India with all locally available materials the supply is guaranteed as well as the price stability. Some recarburiser will be required either for injection or to add to the electric furnace but there are many suppliers and the price is competitive. Electricity for duplexing is also readily available and could be generated if required, as the amount is low compared with electric melting.

It is clear that the cokeless cupola is an economical melting unit and actual operations have shown this to be correct particularly with the cost advantages indicated in this paper. It is therefore clear that Indian Foundrymen should give serious consideration to adopting the cokeless cupola if they want to stay competitive in today's market.