Journal of Metallurgy and Materials Science, Vol. 58, No. 4, October-December 2016, pp. 201-211
Printed in India, © NML, ISSN 0972-4257

Pollution management with techno-economical evaluation for coke based and cokeless furnaces concerning melting and casting of brass and bell metal

D. K. BISWAS* and ARIJIT CHOUDHURY[1]
MIT, Bishunpur, Bankura, West Bengal, India
[1]Megnad Saha Institute of Technology, Kolkata, India

Abstract : India is a very important global player in the casting sector not only of cast iron but also of non-ferrous sector such as brass and bell metal. Melting furnaces of these are mainly coke based. There is also a growing awareness of pollution control levels in the country in recent times and this is a perceived as a threat to the existence of these small scale foundries including melting unit for casting for brass and bell metals scattered in various parts of the country. Attempt has been made to carry out research and development work on developing various modules eco-friendly furnaces concerning melting and of brass and bell metal casting/ product. This paper also discusses techno-economical aspect of the mentioned coke based and coke less furnaces concerning brass and bell metal product.

Keywords : Brass metal casting, Bell metal casting, Coke base furnace, Cokeless furnace, Pollution management.

INTRODUCTION

Since three decade, there has been a decline in the production of ferrous as well as non ferrous casting in industrially developed countries, mainly due to imposition of severe environmental pollution control norms. India is an important global player in the casting sector in both ferrous and non ferrous sectors and the study on ferrous as well as non-ferrous casting reveals that there are numerous cast iron foundries as well as cottage based brass and bell metal industries in India which mainly use coal/coke/ wood / wood charcoal as main fuel. Exhaust emission with flue from these coal/ coke based industries normally carries / emit lots of Suspended Particulate Materials (SPM), Toxic gases such as SO_x, NO_x, etc. much above the limit set by CPCB (Central Pollution Control Board of India) and due to which, it threaten the existence of most of the coke/coal based melting unit/foundry based cottage small scale industries. Normal emission of SPM and SO_x from these foundries is about 1000-3000 mg / NM^3 and beyond 700 mg / NM^3 respectively. The permissible limit of emission set by CPCB on : (i) Suspended Particulate Material (SPM) is about 100-150 mg / NM^3, and (ii) 350 mg / NM^3 for So_2. The Table 1 provides the average discharge analysis of coke based melting furnaces. The numerous numbers of mentioned small scale brass and bell metal product manufacturers mainly utilize coal or coke and wood in various clusters of the country. Operation of these furnaces is reported extremely unhealthy because of the excessive presence of mentioned SPM and toxic gases in the surroundings. Sulfur stripped Liquid fuels promise very low rate emission of pollutant with exhaust flue as indicated in Table 2.

**Formerely Scientist, CSIR-NML, Jamshedpur-831007*

Table 1 : Average flue gas discharge analysis of coke based melting furnaces

A.	Particle size analysis	
	Size range (μm)	Percentage
	> 500	Nil
	150-500	30-35
	50-150	40-45
	20-50	20-10
	< 20	10-5
B.	Flue gas analysis	
	SO_x	400-1000 mg/Nm^3
	NO_x	61-108 mg/Nm^3
	CO	0.2-0.8 %
	CO_2	5.0-8.6 %
C.	Dust load	700-3000 mg/Nm^3
D.	Temperature	400-600^{0}C

Table 2 : Normal emission from coke less cupola

Emission from furnace	Coke less cupola		Recommended limit set by CPCB
	LDO based	Gas based	
So_x mg/Nm	88-90	135-150 for LPG/Propane and ~ 40 for natural gas	350 mg/Nm^3
SPM mg/Nm^3	35-40	8-10	150 mg/Nm^3

Considering the enormity of the problem from the technical, economical and social point of view, an attempt had been made in this work to carry out research and development of eco-friendly furnaces using gaseous fuel such as LPG (Liquid Petroleum Gas) or NG (Natural Gas) and liquid fuel such as Kerosene or LDO (Light Diesel Oil) of various sizes for brass and bell metal melting in connection with the possibilities of production of thin section of not only traditional items/ utensils such as lota/small size pitcher, ghara/big size pitcher, tumbler, thali/saucer/plate, flower vase, but also of artifact.

Moreover, the concept of pollution free operation of melting unit concerning small scale industries is relatively new in the country. Hence in this work, attempt has been made to find out the scope of either resource burden or saving concerning operation mentioned coke / coal/ wood / charcoal free melting units.

Background

Historically, precision casting of brass and bell metal product is known since Shang Dynasty (dates back to 1600 BC) when the lost wax process was first known to be used. However, it has been since last 70 years that the greatest developments in technique of precision casting taken place. More recently, investment casting have been introduced for producing precision casting light alloys (including magnesium and aluminum alloys) and steels (including alloy and tool steel, nickel-chrome, cobalt-chrome, copper base alloys, etc.). Techniques of precision casting have been applied to meet requirement of complexity and accuracy which would not have been possible using conventional methods. Possibility the greatest advantages offered by this

process are that dimensions remain consistent from casting to casting, the metallurgical characteristics of the casting are good, and very intricate parts can be produced by semiskilled laborers. Metal craft is perhaps the single most important craft in terms of the number of artisans engaged in its practice as in its close links with the daily lives of the people of the State/ country. The craft is practiced by the people of the Kansari caste who can be broadly described as metal smiths while a particular variety, dhokra, is practiced mainly by sithulias. The largest concentration of the former is Kantilo and Balakati in Puri district although fairly substantial numbers are found in Cuttack, Ganjam and Sambalpur districts of Orissa.

The workshop is called sala or shed and consists of a platform with a block of stone for the floor on which the beating is done, a heating furnace or bhati, a raised verandah and the sala is provided with a locally made lathe for polishing. Tools used are hammers and anvils, pincers, hand drills, files and scrapers. The heating furnace or bhati with a crucible is fanned by a blowers (leather bellows) although of late the craftsmen have started using mechanical blowers. The process consists of preparation of the material by melting the required materials in the crucible and then placing the molten metal into an earthenware container. After the molten metal sets, it is taken out and after repeated hammering and beating is given the desired shape. Sometimes for making a single item two or three pieces are separately made and joined mostly with rivets or by weld/ brazing. The major items manufactured in the beating process are plates or 'thali', deep round containers called Kansa, small containers called 'gina' (tumblers), water containers called gara and buckets or 'baltis', large cooking utensils and storage vessels called 'handi', various types of pots and pans, ladles or chatu, perforated flat cooking spoons etc. While the above mentioned are items used in cooking and eating, there are also a number of items used for puja or worship. Of these most important, of course, is the ghanta or the gong and thali for offering of the food to the deities. It may be mentioned here that in a few places the surface of the items are also engraved with various designs including floral and geometric patterns besides human and animal figures and occasionally they are also painted with enamel paints. The items produced by the beating process are many and the designs also vary from place to place.

As for casting one can make two broad groups that are brass castings and dhokra casting. Both follow the lost wax process. Brass casting is done by the Kansaris and items produced include icons-mainly Radha, Krishna, Laxmi, pot bellied Ganesha, Vishnu and crawling Krishna called Gurundi Gopal, bells or ghanti, lampstand or rukha and lamps or dipa. It is interesting to note that at present there is no bronze casting being done in Orissa although the craft seems to have reached great perfection centuries ago as evidenced for the discovery of a large number of bronze icons from Achutarajpur near Banapur in Puri District. Again no casting is done in bell metal although this is quite common in South India. The socio-cultural links of its handicraft are very strong.

Of the major icons mentioned is to be made of the large brass image of Radha in the Sakshigopal temple in Puri district and similar images in temples in Ganjam district. Similarly the use of 'Ghanta' and 'ghanti' the bell and the gong are both important and indispensable for all ritual worships, particularly during arati and offering of food. During the Rath Yatra or Car Festival, hundreds of the gongs are beaten rhythmically by the devotees and priests in frenzied ecstasy as the divine chariots are pulled forward by the thronging millions. The manjira or gini, two circular cupped convex discs tied to strings and used for beating the rhythm and the ghunguroo or ankle bells tied in the feet of dancers are also products of this group of crafts and are in indication of their whereabouts. The sound of the cattle returning to the village after the

day's grazing mixing their sweet bleating with the jingle of the bells leaving a trail of dust cloud is a familiar scene of rural Orissa.

Dhokra casting, a variety of metal casting is essentially a folk craft and is limited to a few pockets of Orissa that is Kuliana in Mayurbhanj district, Kaimatin in Keonjhar district, Sadeiberni in Dhenkanal district and Haradagaria in Puri district being practiced by an aboriginal caste called sithulias. While the lost wax process is followed the raw materials used is not pure brass but contains miscellaneous scraps of other metals which give it is typically antique look. Of late, some utilitarian articles like candle stands, ash trays and pen stands are also being made keeping the essential folk design intact.

Dhokra is not exclusive to Orissa and is found also in Bengal, Bihar and M.P. also but it is a very important handicraft because of its more or less exclusive folk character. Kenjakura is a village/cluster situated in the bank of river Darkeswar in the district of Bankura, West Bengal which is more than 150 years old. Presently, about 300 hundred families with about 2500 working people are engaged in this profession. The main products of this cluster are traditional bell metal utensils mainly plates of different sizes, container, glass and other gift items mainly for regular uses and bell.

In the present practice, oven/ furnace for brass and bell metal deals with pre heating, heating and superheating concerning melting and casting through burning of coke/ coke breeze/ charcoal/coal/wood chips. The fuel [especially coke/ coke breeze] accomplish the following essential features :

– The necessary heat for not only heating, melting, superheating of mould along with its flux but also maintaining temperature of furnace inside along with permeable bed of coke chips / coke breeze.
– To provide the necessary permeable bed of fuel in order to provide chocked free flow generated flue.

The mentioned coke based furnace operation contributes toward damaging the surroundings. In fact, environmental hazard expected due to Coke based operation: Exhaust gas emission with flue from coke/coal based foundries normally carries lots of Suspended Particulate Material SPM) from 1000~3000 mg/Nm^3 and SO_X [also NO_X] to the extent beyond 700 mg/Nm^3 respectively. These mentioned emission is severely environmental hazardous and may contributes towards acid rain, ozone layer depletion, green house effect , disruption of food production , and health hazard of human, plants ,animal, and live stock.

Specification set by Central Pollution Control Board [CPCB] : SPM is about 100~ 150mg/Nm^3 and for SO_X is 350 Nm^3.

The feature of coke based furnaces which deal with brass and bell metal casting is shown in Fig. 1 :

Fig. 1 : Photograph of the existing furnace

Mitigation of air pollution in Cast Iron foundries are now achieved by incorporating either GCP [gas cleaning plant] in coke based foundries or installing eco -friendly coke less [LPG or NG based gas fired or LDO/oil fired] melting furnaces (similar to coke-less Cupola) .

– It is reported that additional installation cost and operating cost due to incorporation of any GCP attached to any coke based furnace is much higher than that of coke less cupola. SPM and SO_X generation in coke less cupola is ~ 9-35 mg/Nm^3 and ~88- 150 mg/Nm^3 respectively which are much less than the recommended value specified by CPCB.

– Survey on analytical and engineering support also carried out which included the following : (a) various aspect of liquid and gas burners considering characteristics such as fuel consumption, turn down ratio, short / long length flame, adiabatic flame temperature, operating workable pressure, etc. (b) gas flow dynamics of flue from burner tip to chimney exit through furnace annulus, expected resistance flow considering : kinetic of combustion, restricted flow through openings and permeable bed , flow through nozzles/ restriction, jet behavior, heat and mass transfer, stream functions, fluid elements rotations/spiral movement, and (c) design engineering requirement for shaft furnace, etc.

Several visits were made to various clusters of Brass and Bell metal small scale industries of West Bengal especially at and around Bishnupur of the Bankura district and also participated not only thorough discussion with Practitioners/ Artisans but also witnessed some of the present practices in order obtain in situ knowledge concerning mentioned development. The data obtained: (i) Product weighs- 4.6 kg. (ii) Furnace operating temperature maximum: 950^0C. (iii) Coke consumption 10 kg - for 1st product and, 8kg- for subsequent product- melt. (iv) 2- heats in summer, 3- heats in winter. (v) Working ambience was found encompassed with excessive smoke. (vi) Lots of ash found collected in the furnace bottom pit.

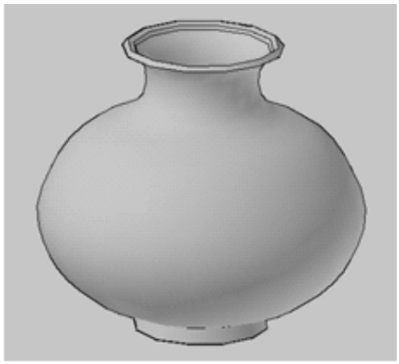

Fig. 2 : A normal Utensil Products - Ghara / Kalsi (Pitcher)

Based on mutual agreement with an entrepreneur and self financing, an eco-friendly furnace was envisaged to design and develop in order to deal with melting and casting of about 5 kg standard Kalsi [standard water container] as shown in Fig. 2.

Present Work

The present work was carried out in the following chronological order of events :

– Design and development of a green technology based furnace for rural based small scale industries / Artisans concerning making bronze made utensils (4.0 kg ~ 5.0kg Ghara). Entire development was conducted through self financing in the following ways :

(i) Visit a number of clusters of rural based industries and artisan and discussed on: (a) their saleable product and concerned melting units, (b) expected damage caused due to generated of air pollution by the coal/coke firing used in melting and subsequent inhaling, (c) witnessed and participated in campaign run of existing coal/coke based melting units.

(ii) To utilize either gas burners (blow torch type) or oil burners (blow lamp type). Gas burners are of naturally aspirated whereas oil burners are operated by compressed air [based on manual operation] were chosen. These cheap and available burners do not require any additional electrically or D G set.

(iii) As coke provide three basic functions i.e. : (a) supply necessary heat, (b) accomplish the purpose of permeable bed and (c) also take load/ burden of entire bed of furnace including that of mould. In order to provide the mentioned function in coke less furnace the following step was taken into consideration :(a) necessary heat to be made available by combustion of liquid fuel, (b) Permeable bed of refractory ball or is made from used and rejected graphite electrode chips [by breaking and shaping (~ + 35mm, -45mm size)]. The bed of about ~250mm to 400mm high is placed along the annuals within the furnace and around the mould to accomplish functions of heat sink from flue as well heat source to mould with raw material, and (c) grate bar to take care of entire load/ burden. Permeable bed is envisaged to allow not only resistance less flow of flue ejected from burner but also holding/ storing heat/ enthalpy from flue available at high temperature around mould.

(iv) The furnace lining [100mm] is provided by using mixture of 70% clay and 30% cast able alumina refractory.

(v) Using Computational Fluid dynamics modeling/ technique is made to increase as much as possible the retention time of flue within the working space of the furnace in order to obtain increased efficiency considering very high flow tangential entry of emitted flue from burners and normal upward draught. One burner was located just above / around the grate bar and another was placed diametrically opposite to earlier one and at a higher level of about 325 mm above the grate bar.

(vi) To measure temperature of mould as well as exhaust flue at the chimney top, Iron-Constantan thermocouple with multi meter [milli ampere/volt-meters] are incorporated.

(ix) The design and developed furnace having working dimension: (a) internal diameter - 400mm?, (b) height- 900mm. The outer shell is to be made from available oil drum shell [3mm thick] for melting [4.0 kg ~ 5.0kg] unit based on using of sulfur stripped available either domestic LPG, or Kerosene / Light Diesel Oil [LDO] as shown in Fig.3 was installed in the premises one of the entrepreneur, i.e. M/s Bimal Shikary, Matukgunge, Bishnupur, Bankura - 722122. West Bengal. The furnace is utilized for subsequent demonstration trial concerning making of brass and bell metal product.

Fig. 3.1 : Photograph of a Blow Lamp

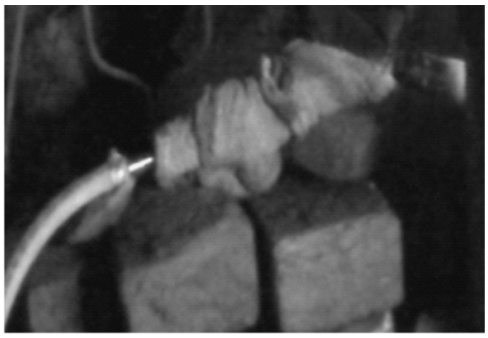

Fig. 3.2 : Photograph of a Blow torch

Fig. 3.3 : Photograph of the Developed Furnace during taking out of heated mould

Fig. 3.4 : Photograph of the Developed Furnace indicating burner in action

EXPERIMENTAL TRIALS

In order to prove the validity of the mentioned design and development, number of the trials was planned, carried out and described in the following section :

i) Kerosene operated : 2 no's of 2lit lamp was tried initially and found unsuitable as maximum temperature obtained was 570^{0}C [against desirable ~950^{0}C]. However stabilized combustion of the lamps obtained.

ii) Blow lamp did not function well with diesel oil during the trials and it was concluded/ envisaged that at least either 4-nos of 4lits capacity or 2-nos of 8lits capacity blow lamp would suffice the desired purpose. However during trial, stabilized flame was not established. Lots of gum with fume was found accumulated over lamps mouth.

iii) Switched on to Gas blow torch [0.2 to .08 hr/hr capacity] using LPG [trials carried on later], higher temperature unto 620^{0}C against desirable ~950^{0}C obtained. Exercise was stopped for subsequent medication: to place/ locate burners-one near/ around bottom support and place opposite at higher level [325 mm above the lower one] and to relocate graphite restrictor/permeable bed to obtain desirable temperature of bed and around mould.

iv) Trials carried out on 1-4-2014, and within 2hrs of operation desirable temperature [~950^{0}C] was achieved. The trial was the switched off for carrying out subsequent melting and casting operation.

v) Trials carried out on 8/4, 15/4, /22/4 -2012 where successful and sailable production of ghara/kalsi obtained. LPG consumption was recorded as : 1.2kg/hr from burner set (2 nos), ~ 4.8kg consumption during 4 hrs operation, furnace temperature recorded was ~11500C, Maximum exit flue temperature ~4500C. Trials were witnessed 6 similar product manufacturer.

vi) Some more successful trials [on 26/5,and 27/5 2012] conducted for melting of cast iron in graphite crucible, and 4.6 kg bell metal melting using 4 no's, 4 lits capacity kerosene blow lamp.

These mentioned trials revealed not only the success but also usability of developed green technology.

The following are some parts produced during afore mentioned trials :

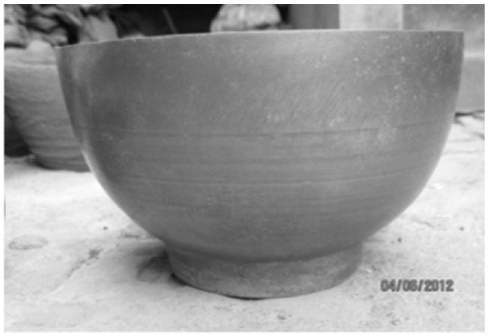

Fig. 4.1 : Photograph of bottom half of Ghara [Bishnupur -type] produced in some trial

Fig. 4.2 : Photograph of Upper half of Ghara [Bishnupur -type] produced in some trial

Some demonstration tests and trials of the developed furnace only with LPG were carried out by incorporating standard pollution measuring device to ascertain to test extent of pollution generated [for SPM and CO_2 level] during the mentioned trial period. The figures were recorded as :

(I) With : LPG

1	SO_x mg/Nm^3	135-165 mg /Nm^3
2	SPM mg / Nm^3	35-40 mg / Nm^3

Results of pollution level obtained by trials based on using LPG were extremely encouraging. Therefore, it can be hopefully predicted that the either LPG or NG based developed Furnace for melting and casting of brass and bell metal is eco friendly.

OBSERVATION

(i) Available Blow torch type burner based on using either LPG or NG is safe, suitable and acceptable for the immediate use in rural base melting furnaces.

(ii) Working ambience of acceptable quality is bound to improve with LPG based furnaces.

(iii) Kerosene burner provides better ambience but that is inferior to that is provided by LPG.

(iv) Firing quality of Kerosene burner is not good as frequent stoppage due to soot formation noticed. However flame stabilization Kerosene stove is better than that of Diesel operated one. Moreover, Combustion characteristic of LPG using blow torch were noticed absolutely hassle free and smooth

(v) This work aims mainly at the possibilities of pollution abatement of rural based casting industries where economic analyses seems to secondary. However, economic analyses carried out are presented in this chapter.

Economic consideration based on conversion cost against the use of various types of Fuels :

I: Capital expenditure

Sl. No.	Type of Furnace	Description	Expenditure	Remarks
1.	Present Coke based Unit	Furnace [clay, refractory & anchoring] + Temp Measuring Device + Gas cleaning Plant	Rs 10000/- + Rs 3000/- + Rs 20000/-	(I) Total Rs. 33000/- (ii) for comparison, incorporation of a GCP unit to be taken into consideration.
2.	Coke less units	[Furnace (clay, refractory & anchoring) + (Burner holes, Grate Bars, Permeable chips lining) + (Burners + Temperature Measuring Devices)] without GCP	Rs. 20000/- + Rs. 2000/- + Rs. 3000/-	Total Rs. 25000/-

II. During operation (for one half of a Ghara)

Sl. No.	Fuel and Accessories	Rs/kg	Consumption Rate	Total	Sum Total Cost/Rs
1. (i)	Common commercial coke	18/- The cost of tone wise foundry grade coke is 22000/- to 28000/-	10kg	220/-	180/-

1. (ii)	wood	8/- per kg-	2 kg	16/-	16/
1. (iii)	Ash handling	-	-	34/--	34/-
1.(iv)	GCP (Minimum running & maintenance Cost)	-	-	50/-	50 /-
Total					280/-
2. (i)	L.P.G	Rs 650/- for unsubsidized 14.5 Kg cylinder and Rs 1600/- for 19 Kg industrial cylinder (1600/19)=28.5	3.5kg 3.5kg	45/-X3.5 Rs 85/- X 3.5	160 297/-
2. (ii)	Permeable bed/ chips	0.1% per kg melt~0.005Kg	Rs 1000/-	2.5	10
Total					(i) Rs 170/- withdomestic LPG or (ii) Rs. 297/- with industrial LPG
3. (i)	Kerosene	Rs 40/- (available market rate}	7.2kg	40/-X 7.2	288/-
3. (ii)	Permeable bed/chips	0.1% per kg melt~0.005Kg	Rs 1000/-	2.5	10
3. (iii)					298/-
4.(i)	CNG	(i) Rs34.45/kg at Delhi through pump station	5.4kg Based on Calorific value comparison	Rs 5.4X34.45	Rs 187/-
4. (ii)	Permeable bed/chips	0.1% per kg melt~0.005Kg	Rs 1000/-	2.5	10
Total					Rs 197/-

III. During subsequent melt :

Sl. No.	Fuel and Accessories	Rs/kg	Consumption Rate	Production rate	Total Cost
(i)	Common commercial coke	18/-	7kg	7X18=Rs 126/-	Rs 126/-
(ii)	L.P.G	Rs 45/-, Rs 85/-	2.25Kg	Rs 102/-, Rs 192/-	Rs 102/-, Rs 192/-
(iii)	Kerosene	Rs 40/-	3.45kg	Rs 138/-	Rs 138/-
(iv)	CNG	Rs 34.35/-	3.5Kg (Based on Calorific value comparison)		Rs 120/-

In the above context the following head wise expenditure is not considered.

– Cost due to Manpower , Electricity, Raw materials, Profit is not included/ considered

– A consumption rate of CNG is estimated by comparing Caloric Values of LPG with that of respective CNG.

CONCLUSION

The work reported concerns with LPG based furnace for brass, bell metal and iron melting and casting and the said development is found successful, acceptable also directed towards new second generation of metal melting furnaces concerning casting. Incorporation of the reported type of furnace based using either LPG or CNG is expected to ensure not only production cheaper product but also clean ambience for subsequent expected health improvement of rural population, live stock and crops.

ACKNOWLEDGEMENT

The information reported in this article is the work of many teaching, technicians and the then final year students of Mallabhum Institute of Technology, Bishnupur, Bankura. Authors are highly thankful to them. Special gratitude to Mr Bimal Sikary and his family for their constant help, and especially for providing their workshop and premises at Bakut Gaunge, Bishnupur for development of the furnace,, arranging for LPG bottles as well as Liquid fuels and for conducting Trials spread for months.

REFERENCES

[1] Taft R.T., (1986), The economics of coke less cupola melting, the British Foundry men, **79**(10).
[2] Taft R.T., (1988), Successful fuel for melting of coke less cupola, Modern casting Production, pp. 28-30.
[3] Taft R.T., (1993), The modern coke less cupola. Foundry Trade Journal 19 (3467), **167**, pp. 26-28.
[4] Ducker, (1989), Cupola 2000 for long term operation with oil or gas firing. Indian Foundry Journal.
[5] Grchev V.A. et al. (1975), Experience in the operation of gas cupola. Russian Casting Production.
[6] Coke less Cupolas Ltd., The coke less cupola in Japan. Foundry Trade Journal (1995).
[7] Biswas D.K. et al., (2001), Pollution management with techno- economic evaluation for coke based and coke less cupolas. Applied Thermal Engineering, **21**, pp. 359-379.
[8] Richards G., (1979), Precision casting, The British Foundry man, pp. 162-167.
[9] Bagman M.L., (1969), Manufacturing Process, Asia Publishing House, Newyork.
[10] Singh S.D., (1999), Eco-friendly coke less cupola, NML, Technical Journal, **41**(1), pp. 1-12.
[11] Perry's, (1961), Chemical Engineering Handbook, 6th Edition, pp. 6.20 - 6.23
[12] Fox RW. and A.T. McDonald, Introduction to Fluid Mechanics, Fifth Edition, John Wiley &Sons INC.
[13] Holman J.P., Text Book on Heat Transfer.
[14] Brass, Copper & Bell Metal Utensil/Utility Products - Khadi & Village Industries Commission - Project Profile for Gramodyog Rojgar Yojana.
[15] GOI, Brass & Bell Metal - Ministry of Small Scale Industries, Small Industries Development Organization - Diagnostics Study Report of Brass & Bell Metal Cluster at Balakati, Khurda, 2005 - 2006.
[16] Basak D.K., Experience with Cokeless Melting Furnace - Executive Director, Wesman Engg. Co. Pvt. Ltd.
[17] Introduction to Environmental Engineering from Google search.
[18] Choudhury Arijit, (2016), Some aspects on the scope of development of various modules of furnaces and flow analysis to it concerning iron, brass and bell metal casting, Ph.D. dissertation, Jadavpur University.