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Development of an alternative ladle covering compound from flyash for blast furnace ladles

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Abstract

Rice husk ash (RHA) based ladle covering compound (LCC) is commonly used in steel industry to reduce the temperature loss while transferring hot metal from iron making units to steel making units. In the present work, an alternate low cost ladle covering compound has been developed and tried at plant scale to reduce the cost and effective use of process waste. The new compound consists of fly ash containing 6-12% carbon to meet the properties required for ladle covering compound. Physical, chemical and thermal properties of both the RHA and flyash based LCC were studied. Operational parameters such as spreadability, melting, track-time temperature loss, ease of ladle cleaning, elemental pick up by liquid metal, specific consumption etc. were monitored during trials. While the physical, chemical and thermal performance of the new compound was at par with RHA based compound, the specific consumption has reduced by 10% resulting in reduced dust level during usage and cleaning. Flyash contains less alkali as compared to RHA based LCC which is advantageous to ladle refractory life.

Keywords: LCC, Flyash, Spreadability, Melting.

1. Introduction

Use of ladle covering compound is a common practice in steel industry to avoid/minimize the heat loss during molten metal transfer. Iron making units of COREX and Blast furnace at JSW Steel Vijayanagar units are currently using rice husk ash (RHA) based ladle covering compound in hot metal ladles. LCC spreads and flows freely on the surface of liquid metal by creating a thick layer of 1-2 inches and controls the heat loss during transfer of hot metal. Flyash contains 45-50% SiO2, 25-30% Al2O3, 5-10% CaO and 6-12% unburnt carbon.

RHA contains major portion (85-90%) of amorphous silica and rest are other oxides such as MgO, CaO, Na_2O, K_2O. It acts as good thermal insulator with melting temperature of more than 1350°C [1]. Most of the literature describes the applications of flyash and RHA as filler material for concrete, Ceramic Glaze production, bricks making, geo polymer concrete making and water filter media [2-4]. At JSW Steel, currently RHA mixed with aluminum dross based LCC is being used. It is found that flyash is having similar characteristics of RHA with respect to size, chemistry and thermal properties. The major requirements of an LCC are spreadability and low specific gravity for floating on the metal surface and not to form crust by forming a thick solid liquid composite layer on the metal surface [1-5]. It is found that very few literature is available on usage of flyash as ladle covering compound as a replacement of RHA. Riccardo Carli et.al. described that rice husk ash has been historically the first to be employed as tundish covering material. Silica present in RHA undergoes a phase transformation from amorphous to crystalline at temperature above 850°Cwhich is a critical aspect related to working environment concern. Thermal conversion of SiO_2 into crystalline cristobalite make it health hazard. This is one of the major driving forces in substituting rice husk ash based materials with low silica contain materials such as flyash [5]. Mostafa et.al.explained the health hazards occurs due to usage of aluminum dross in different applications [6]. It is also observed at JSW blast furnace that RHA/ aluminum based LCC are emitting more smoke after spreading on the metal surface of ladle due to the presence of unburnt organic substance and presence of aluminum dross in it.

During the process of transferring liquid hot metal from iron making to steel making units, temperature loss occurs is of around 200-250^{o}C. Insulating materials are used to reduce the temperature loss by covering on the top surface of the hot metal ladle. Presently a rice husk based product which is purchased from outside is using as Ladle Covering Compound (LCC). In the present study, trials are conducted in blast furnace no.2 of JSW Steel Ltd. Vijayanagar works by replacing rice husk based LCC with fly ash. Fly ash is the ash generated after burning of coal in power plant. Fly ash acts as insulator by reducing the hot metal temperature loss during transfer from iron making to steel making. With the usage of RHA based LCC, hot metal temperature drop will be in the range of 100-150^{o}C. With the usage of fly ash LCC hot metal temperature drop while transferring is almost same as in the case of rice husk based LCC. Series of trials are conducted in Blast Furnace-2 and Corex-1 by using fly ash of around 5 tons and found that results are encouraging. Trial results and techno economic benefits are evaluated.

LCC is a flux material which acts as insulating material on the surface of hot metal with good spread ability, so that it spreads instantly to cover hot metal surface completely in the ladle to prevent heat loss while transfer from iron making to steel making units. LCC powders are used in the cast house to reduce the heat loss in the ladle while transferring the hot metal from iron making to steel making units.

Required characteristics of a good LCC are as under;

- Good insulation to minimize the hot metal temperature loss during transfer
- Good spreadability on the hot metal surface
- No crust formation on the top of the ladle
- Less emission of dust & fumes during handling and ladle movement
- Not to react and contaminate the hot metal
- Lower density than hot metal for floating on the hot metal surface
- Avoid skull formation and reoxidation

2. Experimental

In the present work, an alternate low cost ladle covering compound has been developed and established at JSW leading. The new compound consists of fly ash from power plants and spent refractory in proportion to meet the high temperature properties required for ladle covering compounds. Comparison of both the materials was done for evaluating their suitability, i.e., with respect to granulometry, chemistry, and high temperature flow properties.

2.1 Characteristics of RHA based LCC vs Flyash LCC

Chemical analysis of both the RHA based LCC and flyash LCC are given in Table 1. Chemical analysis was done using X-ray Fluorescence (XRF, Thermo Scientific, Model No– ARL 9900) spectrometer. Chemical analysis shows that RHA LCC contains low silica and high alumina compared to Flyash LCC. This is due to usage of aluminum dross in RHA based commercial LCC.

Table 1: Physical and Chemical analysis of RHA based LCC & Fly ash

Property	RHA based LCC	Flyash LCC
SiO_2, %	27.0	49.0
CaO, %	3.70	4.70
MgO, %	6.20	1.43
Fe2O3 , %	4.70	7.50
Al2O3, %	43.40	25.0
Alkali (Na_2O + K_2O), %	6.80	1.25
MnO, %	0.20	0.05
TiO_2, %	0.50	1.63
SO_3, %	0.45	0.46
CuO, %	0.49	0.01
ZnO, %	0.42	0.08
PbO, %	0.35	0.03
Sulphur, %, %	0.42	0.17
Carbon, %	4.00	8.00
Phosphorous, %	0.05	0.21
Moisture, %	2.30	0.40
Density, gm/cc	1.10	1.20
LOI @ 900ºC	7.30	10.00
Fusion temperature,^{o} C	>1494	>1489
Colour	Dark brown	Grey

Size analysis of both the RHA based LCC and flyash LCC are given in Table 2. The size analysis shows that the flyash is finer (150µ: 74%) as compared to RHA based LCC (1000µ:97%).

Table 2: Particle size analysis of rice husk based LCC & Fly ash

Size fraction, µ (cumulative passing)	RHA based LCC	Fly ash
44	0.1	2.7
74	0.2	18.4
105	2.7	47.0
150	5.4	74.0
250	8.8	77.0
500	46.9	95.1
1000	97.0	99.6
1190	100.0	100.0

Micrographs of RHA based LCC and Flyash LCC is shown in Figures 1 and 2 respectively. Flyash particles are found spherical in shape while RHA based LCC particles are irregular/flaky in nature.

2.2 **Ash**

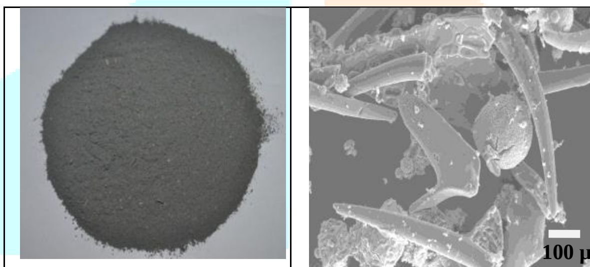

Fig. 1: RHA based LCC and its micrograph

Fig. 2: Fly-ash LCC and its micrograph

Fusion analysis of LCC:

Ash fusion test (HESSE Instruments, Model No- EM201-17K in oxidizing atmosphere) details are given in Figures 3 and 4 respectively. It is observed from Figures 3 and 4 that the fusion characteristics of both the Flyash LCC and RHA based LCC are almost similar.

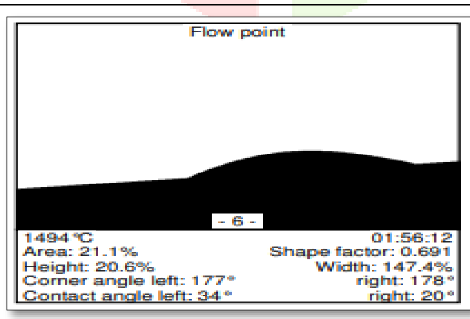

Fig 3: Ash fusion of RHA based LCC

Sintering temperature, ° C	1086
Deformation temperature, ° C	1306
Sphere temperature, ° C	1410
Hemi Sphere temperature, ° C	1438
Flow temperature, ° C	1494
Deformation range	1306-1438
Flow range	1438-1494

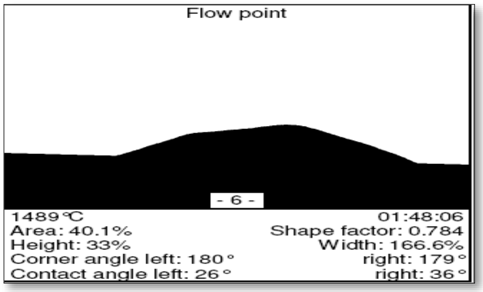

Fig 4: Ash fusion of Flyash LCC

Sintering temperature, ^{o} C	1081
Deformation temperature, ^{o} C	1291
Sphere temperature, ^{o} C	1388
Hemi Sphere temperature, ^{o} C	1447
Flow temperature, ^{o} C	1489
Deformation range	1291-1447
Flow range	1447-1489

2.3 Plant scale trials:

Plant scale trials were conducted in Blast furnace #2 & Corex #1 units of JSW steel Ltd. using flyash LCC containing 8% Carbon as full replacement of RHA based LCC in 70 ladles. Around 45 kg of flyash LCC was used in every ladle of having throat diameter of 1.5 m with LCC layer thickness of 25-30mm. Figure 5 shows the schematic diagram of ladle covering compound usage in ladle and figures 6&7 shows the plant scale trial ladle images with RHA and flyash LCC.

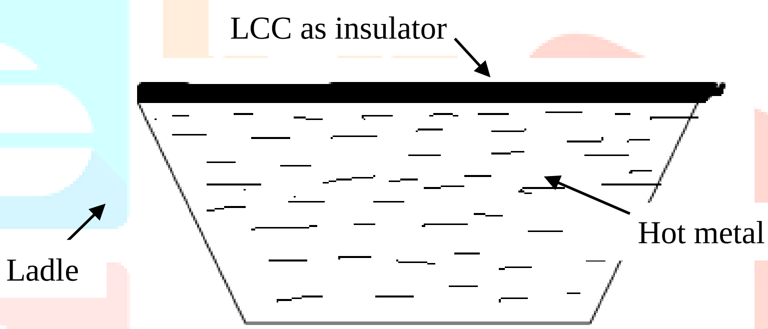

Fig 5: Schematic diagram of LCC usage in hot metal ladle

3 Results and discussion:

Characterization studies of flyash and RHA based LCC are shown in Table 1. It is observed that flyash is finer in size and particles are spherical in shape which helps in better spreadability and coverage in hot metal ladle as shown in Figures 6 & 7. The lower alumina in flyash caused very low fumes when used.

	
Fig. 6: RHA based LCC in ladle	Fig. 7: Flyash LCC in ladle

RHA based LCC contains relatively high alumina (43.4%) as compared to Flyash LCC (25% alumina) which generates relatively more fumes. No process abnormalities were observed in blast furnace, Corex cast house, Ladle Repair Shop (LRS) & Hot metal Pre-treatment (HMPT) units. Hot metal chemistry also not disturbed due to the usage of fly ash as LCC. Temperature drop from cast house to HMPT is well below 150^{o}C which is maximum allowed as per specification.

It is also concluded that fly ash can also be used as Ladle covering compound as a replacement of rice husk ash without affecting the process parameters such as temperature loss, spreadability, metal quality and dust emission. Dust and fumes emission is less in case of flyash LCC compared to RHA which is due to presence of aluminium dross in commercial RHA Aluminium dross LCC. This will also reduce the smoke emissions in cast house due to pre-fused nature of flyash compared to Aluminium. It is also observed that because of low density, high surface area and good spreadability of flyash LCC, consumption is reduced 10% i.e.5kg per ladle.

The variation of temperature loss of the hot metal in ladles with RHA based LCC and flyash LCC are shown in fig 8 & 9 respectively. It is observed that in both the cases temperature loss is varying between 110-130 ^{o}C which is below 150 ^{o}C.

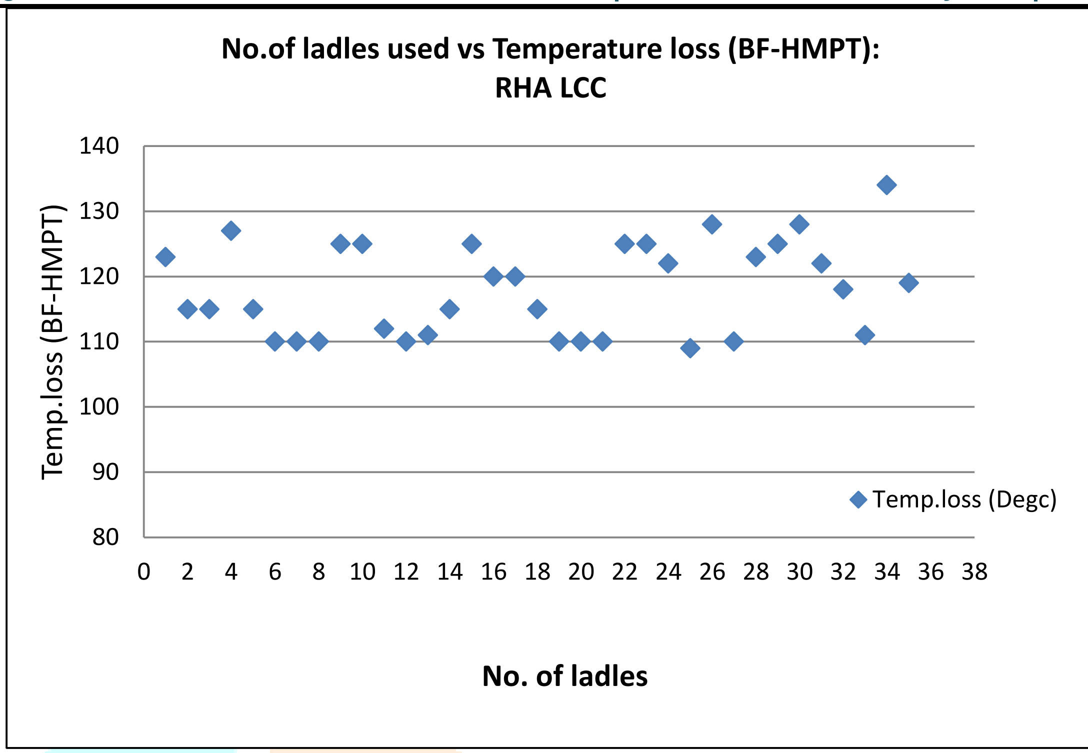

Fig. 8: Hotmetal temperature loss with flyash LCC in BF2

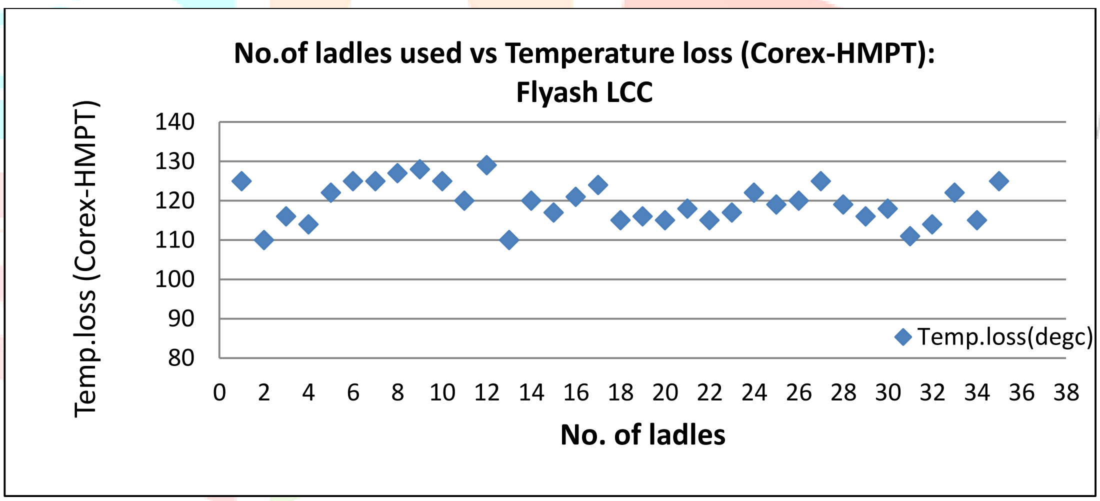

Fig. 9: Hot metal temperature loss with flyash LCC in Corex

The bottom layer of LCC partially melts and forms a viscous layer on the metal surface which floats on the surface of hot metal and acts as insulator during transport. Temperature of hot metal is monitored at cast house after LCC charging and at HMPT station. It is observed that usage of flyash LCC saved 5 kg (10%) of LCC consumption per ladle because of low particle size and spherical shape of the particle.

4 Conclusions

- Flyash can be used as Ladle covering compound as a replacement of rice husk ash without affecting the process parameters such as temperature loss, Spreadability, metal quality and dust emission
- Dust and fumes emission is less in case of flyash LCC compared to RHA which is due to presence of aluminium dross, amorphous silica in commercial RHA based LCC
- Spreadability of Flyash LCC is good compared to RHA LCC. This is attributed due to spherical shape of flyash compared to RHA LCC which is irregular and flaky in nature
- RHA based LCC contains high amorphous silica with high alumina content which is hazardous to the environment when
- Consumption of flyash is reduced 10% when compared to RHA Aluminium dross based LCC because low particle size and high surface area
- Usage of flyash LCC gives substantial cost benefit as well as development of a novel inhouse utilization method for flyash

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