STUDY ON THE PROPERTIES AND PERFORMANCE OF BASIC REFRACTORY MIXES FOR EBT TAPHOLE SLEEVE: EFFECT OF SINTERING AIDS

Smita Satpathy*, Dr. A. K. Samanta, Kido Naofumi, E. Arimitsu, P. B. Panda
TRL Krosaki Refractories Limited, Belpahar-768218, Odisha (India)

ABSTRACT

Repair of a furnace taphole is usually done on hot condition free from molten metal. Typically, refractory sleeves are placed in the taphole. With increased number of tapping the thickness of the sleeve reduces invariably and therefore it is essential to repair the sleeve on regular basis. Repairing around the sleeves is preferred simply because to replace the entire taphole block after it is worn out would require shutting down the entire furnace which usually requires at least 8 to 10 hours of down time. In order to achieve the original taphole diameter, the space inside the sleeve is filled with a basic repairing mix. Therefore, for reasons of economics, the industry has developed an inconvenient procedure of frequent repairing of taphole sleeves. It has been found that a repairing mix which works well for emergency repairs to the taphole sleeve is preferred. The usual time required for emergency repairs of a taphole sleeve is about 30 minutes. The need clearly exists for a longer lasting maintenance material which requires less frequent repair. These materials should have easy installation, high bulk density, fast sintering, excellent resistance against molten metal penetration, and superior erosion/corrosion resistance.

The present study is based on the effect of different sintering aids on the properties of basic repairing material and its performance during application. The hot setting behavior of the dry mass depends on the sintering aids, binder content and curing temperature. Grain sizes and material chemistry are carefully controlled to allow for proper density and sintering. Trials were done with chromate, sulphate and phosphate bonded additives and sintering study was carried out both in rammed as well as site conditions at temperatures ranging from 600°C to 1400°C. The Bulk Density, Porosity, Strength and other high temperature properties of samples were evaluated for all the trials and it was found that at intermediate temperatures the sintering aids plays a vital role during application. The developed material has been tested at different integrated steel plants and the performance is satisfactory.

KEY WORDS: EBT Sleeve, Sintering Aids, Temperature

1. INTRODUCTION

For conventional tapping in electric furnaces, a taphole block with a predrilled hole is the most common construction. Operators ram basic ramming mixes around a steel pipe to form their taphole or gun basic gunning mixes around a steel pipe for the initial taphole. Some taphole designs last till the life of the furnace campaign, while other operators regularly maintain their taphole by ramming around an inserted metal pipe. For EBTs, dense magnesite or magnesite carbon shapes form the vertical taphole. These are often encased within larger rectangular shapes to form a permanent taphole well in the nose of the furnace. Conventional tilting electric furnaces generally use taphole module shapes set with a crane at the proper elevation prior to bricking the slag line and sidewalls. Here they leave an opening in the sidewall rings and then ram around a steel pipe forming the taphole. This pipe is then melted out on the first heat. Therefore, refractory taphole shapes can also be utilized in this same manner with monolithic material holding them in place at the proper elevation and angle [1].

Inorganic bonding agents are now widely used in the production of refractories owing to their properties, i.e. when mixed with water or aqueous acid-base solutions, initially they persist as viscous or paste like mixes, and then convert to monolithic, easily shaped materials [2]. In the last few decades, magnesia – chrome mixes are used as stamp materials around the round tubes of EBT sleeves. But, now-a-days due to the carcinogenic effects of chrome bearing materials, end users of refractories are not willing to use these materials. Certainly, the need for environmental friendly repair mixes arise.

Phosphate bonded refractories are also applied as repairing materials due to their short setting time and good thermo mechanical properties in the 30-1000ºC temperature range [3].The effects of temperature on the properties and constitution of a bond material are of special interest in the field of refractories. Most refractory bonding materials show a zone of weak strength in the range from 500 – 1000ºC where original air-set properties disappear and due to fusion, strength varies significantly [4]. Chemical reactions of phosphate with the raw materials as well as polymerization and poly-condensation of the phosphates take place in refractory bodies with phosphate bond. The phosphate binder reacts first with the mix components, either basic or neutral, with respect to which it possesses the greatest chemical activity. The hardening process of refractory materials depends on the type of cations present as reaction partner for the phosphate binder.The reaction rate and intensity depends on the cation availability of the mix and of its temperature [5].

$$(NaPO_3)n + H_2O \rightarrow NaH_2PO_4$$
$$2NaH_2PO_4 + MgO + H_2O \rightarrow Mg(H_2PO_4)_2 + 2NaOH$$
$$Mg(H_2PO_4)_2 + MgO \rightarrow 2MgHPO_4 + H_2O$$
$$nMg(H_2PO_4)_2 \rightarrow Heat \rightarrow (Mg(PO_3)_2)n + H_2O$$
$$2MgHPO_4 \rightarrow Heat \rightarrow Mg_2P_2O_7 + H_2O$$

Therefore, in the presence of phosphate binders refractory mixtures significantly change their rheological properties in the stages of mixing and forming.

Sulphate is another binder used in basic ramming mixes. In general, magnesium sulphate hydrate is common as a source of sulphate. Magnesium salts react with base material to form magnesium – oxy sulphate compounds on heating and forms a strong bonding material [6] which results in the strength development in the ramming mix.

In the present paper, the effect of different inorganic sintering aids/binders on basic refractory mixes were studied. Two mixes, one with chromate and other with phosphate bonded were tried in an integrated steel plant to assess the suitability of sintering aids/binders to get the enhance performance of EBT sleeve by repairing.

2. EXPERIMENTAL PROCEDURE

In the present work, to know the effect of different sintering aids, a 94% magnesite ramming mass was designed with same weight percentage of chromate, phosphate and sulphate as shown in Table.1. The base material was sea water magnesite having MgO ~ 98% along with 2% additive which was common for all mixes. The properties of different sintering aids are shown in Table.2.

Tab. 1: Different Batch Formulations

Composition	TC	TP	TS
Magnesite (%)	95	95	95
Additive (%)	2	2	2
Chromate (%)	3	X	X
Phosphate (%)	X	3	X
Sulphate (%)	X	X	3

Tab. 2: Properties of Sintering Aids

Sintering Aids	Cr_2O_3 (%)	P_2O_5 (%)	MgO (%)	SO_3 (%)	pH
Chromate	74.8				3.9
Phosphate		62.6			7.4
Sulphate			16.2	32.5	6.6

In all cases, 10Kg sample was prepared as per composition. Dry mixing was carried out in high intensity Hobart mixer machine for 5 minutes. In order to maintain sample size a cylinder of 50mm diameter and 50mm height was pressed with a load of 68.95 Mpa in metal mould cavity, as shown in Fig.1. Keeping the water percentage same for all formulations, samples were pressed and kept in room temperature for 4hrs as per ASTM C975-87 as shown in Fig.2.

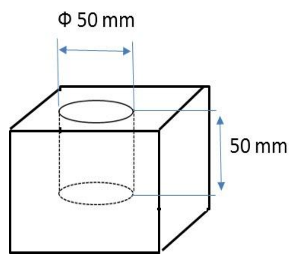

Fig.1. Cavity for sample preparation

Fig.2. Samples after Pressing

Initially all samples were dried at 110˚C for 24 hours and then firing was carried out at 600˚C, 800˚C, 1000˚C, 1400˚C, 1500˚C & 1600˚C with 3 hours soaking time. In Fig.3, samples fired at an intermediate temperature (1000˚C) are shown.

Fig.3. Samples after firing at 1000°C

The physical properties i.e. apparent porosity, bulk density of the pressed samples were determined by Archimedes principle method using kerosene as immersion media. The cold crushing strength (CCS) and permanent linear change (PLC) were measured after firing the samples at different temperatures

3. RESULTS AND DISCUSSION

3.1 Apparent Porosity

The variation of porosity with different sintering aids is shown in Fig.4. It was observed that porosity highly increases with increase in temperature for TS as compared to TC. But, in case of TP, porosity varies uniformly in the range of 14 -16% at different temperatures. In case of sulphates as sintering aids/binder, there is dissociation of salts on heating and formation of magnesium – oxy sulphate. The increasing porosity with increasing firing temperature may be due to the dissociation of magnesium salts into oxy sulphate compounds.

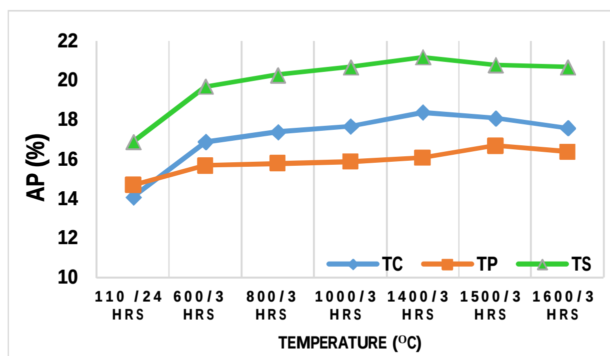

Fig.4. Variation of Apparent Porosity with different Sintering Aids

3.2 Bulk Density

The variation of bulk density at different temperatures with different sintering aids is shown in Fig.5. In sulphate bonded system, density is low and compaction of materials at different temperatures is poor. The lower density is also supported by the higher porosity, with firing at different temperatures. It was observed that TP samples show high bulk density at intermediate temperatures, which may be attributed to the chemical reaction of phosphate with the raw materials.

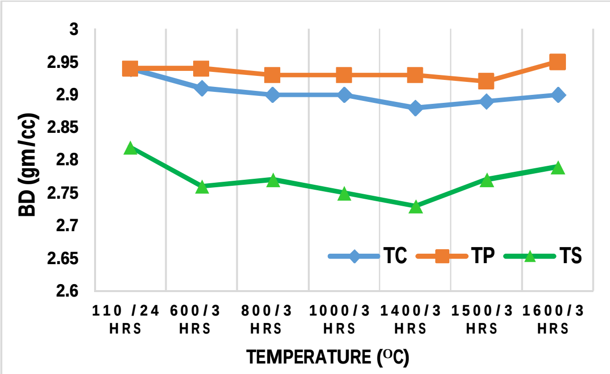

Fig.5. Variation of Bulk Density at different temperatures

3.3 Cold Crushing Strength

Fig.6. shows the effect of cold crushing strength at various temperatures with different sintering aids. It was observed that initial strength is highest for TC, and with increase in temperature it gradually drops at certain intervals. Whereas in case of TP, it was seen that with rise in temperature, strength increases and maximum strength is observed at 1000ºC, which indicates complete polymerization of phosphate binders. Strength is more or less same for TC, TP and TS after 1400ºC, due to the sintering of samples.
So, in order to get sufficient strength at lower temperature (< 1000ºC) it is suggested to design basic ramming mixes with phospate as sintering aids or binder. In some of the cases, particularly for intermediate repairing of EBT sleeve, it is essential to develop sufficient strength at lower temperature to prevent the initial erosion before sintering. Therefore, basic ramming mixes with phosphate as binder are suitable to get extra life of EBT with repairing.

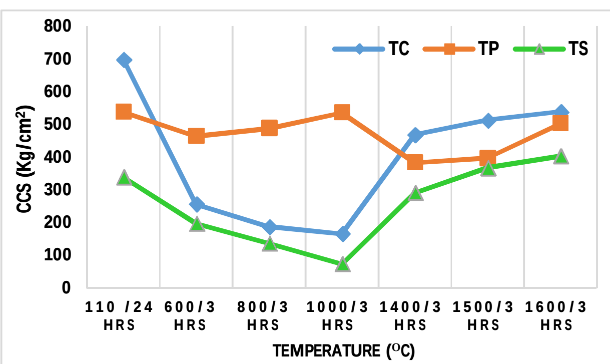

Fig.6. Effect of Sintering Aids on Cold Crushing Strength at various temperatures

3.4. Permanent Linear Change

While firing the basic mixes at different temperatures there was shrinkage in all cases (Fig.7). A sharp change in dimension was observed in between 110ºC to 600ºC for all samples. The higher shrinkage in between 110ºC and 600ºC is due to dissociation of sintering aids/binder and formation of different other compounds. Beyond 800ºC, there was continuous sintering of the mixes which results in further shrinkage with increasing firing temperatures.

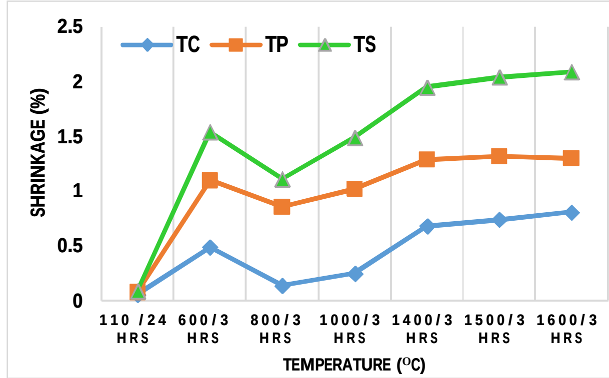

Fig.7. Effect of Sintering Aids on Shrinkage at different temperatures

3.5. FIELD TRIALS

After completion of basic study of sintering aids, field trials were conducted in an integrated steel plant for TC and TP formulations in CONARC furnace with 210 MT capacity. The different operating parameters are shown in Table.3.

Tab.3. Operating Parameters

Operating Parameters	
Tap Weight	210 MT
Tap Temperature	1640ºC
Process Time	65 min
Arcing Time	15-20 min
Tapping Time	2.5 - 5 min
Tap to Tap time	70 - 80 min
Steel Grade	Medium & Low Carbon
EBT life with Repair	180 heats

Fig.8. shows the schematic diagram for a typical EBT sleeve and its repairing with basic ramming mix. During repair, a metal pipe is put inside the sleeve and then ramming material is poured into the gap. Initially, ramming mix is prepared with little more water to ensure proper filling of the gap at high temperature followed by standard slurry condition for the rest of the gap as well as surroundings of EBT mouth which is damaged badly. Temperature during repair is around ~1000ºC, and sufficient strength at this temperature is highly essential to minimize the erosion from hot metal and enhance the life of EBT through repairing.

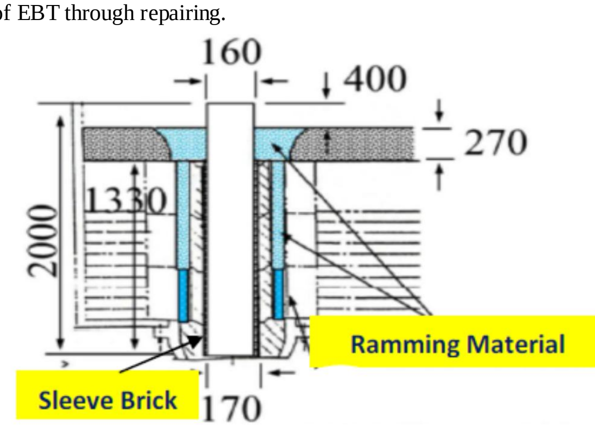

Fig.8. EBT Sleeve Design

The damage behaviour of EBT is directly proportional with the tapping time of hot metal in both the cases for new EBT as well as with repairing as shown in Fig.9. But the slope is different as the rate of erosion is different with the increased life of EBT. Initially, it is observed that with the sharp decrease of tapping time, the initial damage area is erosion of EBT top ramming mass (Fig.10). With the stable decrease of tapping time in stage 2, the erosion of the sleeve and end bricks takes place, resulting in increase of inner diameter.

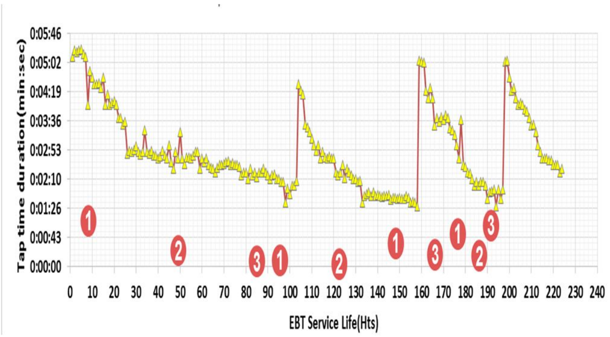

Fig.9. Tap Time Duration vs. EBT Service Life

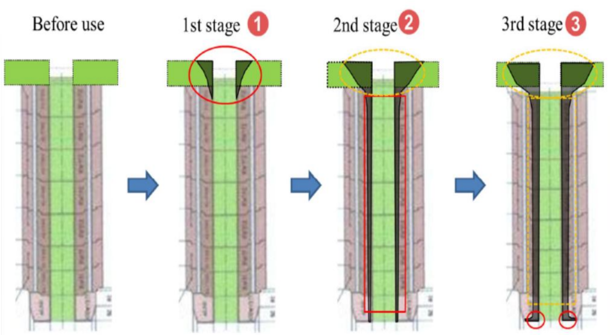

Fig. 10. EBT Damage Pattern

With further decrease of tapping time, i.e. from low tap time to lower tap time, erosion of the end brick tip starts and inner diameter increases uniformly from top to bottom. At this stage, ramming mass is used in slurry condition to extend the service life of EBT sleeves.

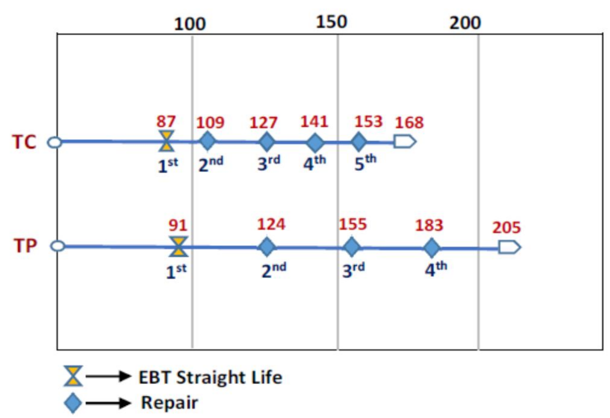

Fig. 11. Comparison of frequent repairs for Chromate and Phospate bonded ramming materials

In field trials, the frequency of repairing of EBT sleeves with TC and TP ramming materials is shown in Fig.11. It was observed that first repairing of EBT was done at ~ 90 heats. But maximum ~ 170 heats life was acheived with five repairing of ramming mix in TC composition. The major issue was high erosion and irregular repairing life i.e. in between 15 – 20 heats. The target life of EBT for this particular plant was 180 heats with maximum 3 - 4 repairing. In case of TP formulation ~ 205 heats life of EBT was acheived which was ~ 35 heats more life than TC formulation and ~ 14% higher than target life. One of the most important things is the uniform repairing frequency for TP formulation. Even the repairing life with TP formulation is ~ 50% higher than TC formulation. The higher life in case of TP is the early strength development (< 1000^{0}C) due to formation of different phosphate compounds at relatively lower temperature which prevent the initial erosion of the repairing mix.

4. CONCLUSIONS

Proper selection of sintering aids plays a vital role in the performance of ramming materials whether it is used in ramming consistency or in slurry form. Binders dissociate with temperatures to form different compounds but the dissociation temperature is different for different binders. In case of phosphate, as a binder it is observed that there is sufficient strength development in between 600^{0}C – 1000^{0}C. In case of EBT repairing mix , early strength development is essential to enhance the life where phosphate as binder is suitable. The other properties like porosity, PLC etc. are also in favour when phosphate is used as a binder. Field trials also indicate that ramming materials with phosphate as binder help in achieving more number of heats with lesser frequency of repairing. Also, the frequency of repairing is uniform and predictable.

REFERENCES

[1] Chapter 10, Electric Furnace Steelmaking J.A.T. Jones, Consultant B. Bowman, copyright 1998, The AISE Steel Foundation, Pittsburgh, PA

[2] A Karpukhin, V S Vladimirov, S E Moizis,“ A mechanism for phosphate hardening and prospects for the use of metal phosphate materials”, Part I, Refractories and Industrial Ceramics, 46[3] 180-186(2005)

[3] A P Luz, G R Oliveira, D T Gomes, V C Pandolfelli, “Monoaluminum phosphate-bonded refractory castables for petrochemical application”, Ceramics International, 42[7] 8331-8337(2016)

[4] WM David Kingarey,“Phosphate bonding in refractories, S.B., Massachusetts Institute of Technology, 25(1948)

[5] V A Chernyakhovskii, “Technology of unfired periclase spinel parts with a phosphate binder”, Refractories, Ogneupory,

[6] Nelson, H. Kehl, Hagerstown, Refractory composition and method of producing same, Patent No – 3,232,774, February 1, 1966