EFFECT OF DIFFERENT ANTIOXIDANTS ON THE PROPERTIES OF STEEL LADLE DOLO-C REFRACTORIES

T. Mahata*, V. Jha, Ch. V. A. Chowdary, A. Acharya, B. Ghosh* and P. B. Panda
TRL Krosaki Refractories Ltd.

ABSTRACT:

Steel ladle refractory always plays a major role to produce cleaner steel. Significant amount of refractory material is consumed in this area. Generally, magnesia carbon material is used for lining of steel ladle. In last few years uncertainty in the availability of high-quality magnesia and price increase experienced by refractory manufacturer and end users. As dolomite is the potential alternative steel ladle refractory due to its high thermodynamic stability and good slag corrosion and erosion resistance, people are thinking to optimize its use in steel ladle.

In this present investigation, behaviour of different antioxidants in Dolo-Carbon refractories has been studied. Purpose of this study is to find a suitable antioxidant of Dolo-C refractory for steel ladle application, which will provide optimum thermo-mechanical property along with best corrosion and erosion resistance. Two different metallic and carbide antioxidants is selected for this purpose. Addition of single antioxidant and combination of both in Dolo-carbon refractory was studied. Variation of physical and thermo mechanical properties was studied along with oxidation resistance. Combination of two antioxidants was found to be more efficient compared to single antioxidant.

INTRODUCTION

MgO-C refractories are being used in steel ladles since a long time. There have been many studies on the property improvement of MgO-C refractory bricks. However, very less research have been performed for the improvement of Dolo-C bricks. Dolomite refractories make good cheaper alternative to the expensive fused magnesia based MgO-C bricks.

Dolomite shows good thermal shock resistance, basic slag resistance and refractoriness under load, thus it is used both in AOD lining as well as steel ladle lining. Major problems associated with dolomite is poor hydration resistance.

During the application in ladle lining, the bricks must withstand huge amount of thermal shock. To improve the thermal conductivity of the material in steel ladle, Carbon in some form is added. This addition improves the thermal shock resistance; however, this can cause poor high temperature properties and carbon pickup during the steel manufacturing as an undesirable side effect. In this study we are trying to improve the oxidation resistance of the Dolo-C refractories to reduce carbon pickup and improving hot properties using antioxidants.

EXPERIMENTAL PROCEDURE:

Sample preparation:

Sintered dolomite and natural flake graphite (94% Carbon content) was used as prime raw materials. Phenolic liquid resin and powder resin was used as binder. Addition of antioxidants was done with addition of fine fraction.

Total 8 nos of batches were prepared. One with regular combination without antioxidant, 3 batches with variation of B_4C content, 3 batches with variation in Si powder content and 1 batch is prepared with a combination of B_4C and Si powder. Details of recipe is given in table.1. R is the brick formulation with no antioxidant. B-1, B-2 and B-3 are the formulations with addition of B_4C and S-1, S-2, S-3 are the formulations with addition of Si metal powder. After observing the properties of above recipes formulation M was optimized in combination with B_4C and Si.

Bricks were pressed in hydraulic press. Tempering of pressed bricks was done in a tempering kiln for 16 hours.

Table.1: Formulations of different batch and abbreviations.

Abbreviation	R	B-1	B-2	B-3	S-1	S-2	S-3	M
Chemical composition (%)								
Sintered dolo	96	96	96	96	96	96	96	96
Graphite	4	4	4	4	4	4	4	4
Boron Carbide (B_4C)	0	+	++	+++	0	0	0	++
Silicon powder (Si)	0	0	0	0	*	**	***	**

Testing methodology:

After tempering bricks were cut in different shapes for property evaluation. 50 mm*50 mm *50 mm cubes are cut to test Apparent Porosity (AP), Bulk Density (BD) and Cold Crushing Strength (CCS). One set of samples were tested as such after cutting the bricks and another set of samples were tested after coking the brick samples at 1600°C/2 hrs in coke bed. Testing of AP, BD was done as per IS 1528.

50 mm*50 mm *50 mm cubes are fired at 1400°C/2 hrs in air atmosphere for oxidation resistance test. After firing bricks are cut and measured the oxidised area and hence percent of oxidation.

Modulus of Elasticty (MOE) test was done after coking the brick samples of 50mm*50mm*100 mm at 1600°C/2 hrs. MOE value was calculated by measuring the velocity of ultrasonic wave inside the sample through sonic test method.

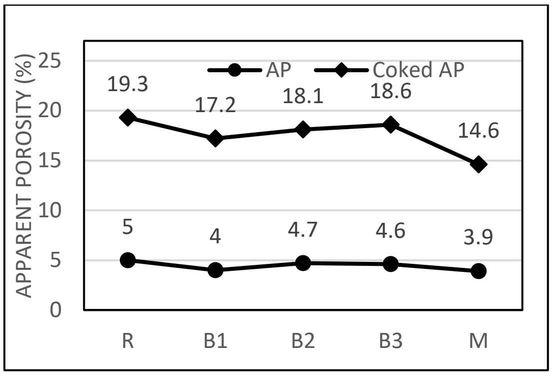

Fig.1: Apparent Porosity (%) of as such and coked samples with B_4C antioxidants.

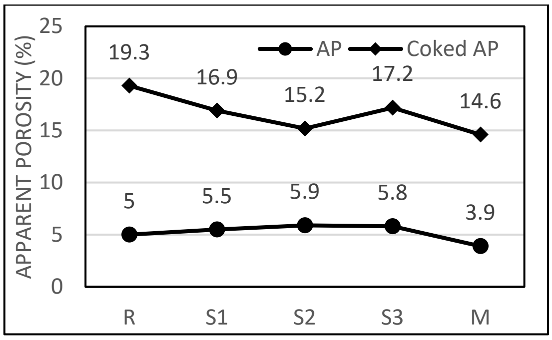

Fig.2: Apparent Porosity (%) of as such and coked samples with Si antioxidant.

RESULTS AND DISCUSSION:

Fig.1 shows the variation of AP%) of samples containing B_4C and compared with regular sample R (without antioxidant) and sample M (contains both the antioxidant B_4C & Si). It is observed that there is no such variation of AP(%) for the samples without coking. Here there is a contribution of resin binder to keep AP(%) within the limit. Same thing happens in fig.2 for Si added samples. After coking AP(%) decreased due to addition of antioxidants. It indicates that antioxidant forms liquid phase and reduce open pores of the bricks. It also show that Si containing samples has lower AP(%) compared to B_4C containing samples. And Si+B_4C containing sample shows lowest AP(%).

In Fig.3 and 4, it shows that there is no significant variation of BD of the samples due to addition of antioxidants. Similarly after coking samples does not shows any significant variation with addition of different antioxidants.

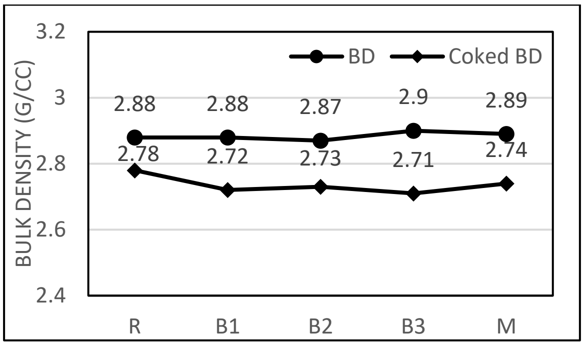

Fig.3: Bulk Density (g/cc) of as such and coked samples with B_4C antioxidants.

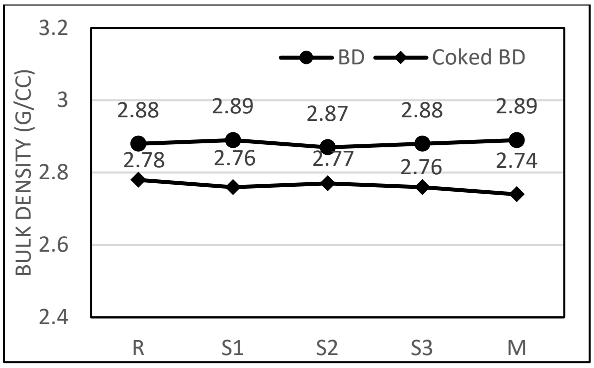

Fig.4: Bulk Density (g/cc) of as such and coked samples with Si antioxidant.

Addition of Si and B_4C shows the decreases in CCS value of without coking samples. This CCS value is associated with crosslinking of resin. Addition of antioxidant in fine fraction restricts the crosslinking of resin upto some extent but it may be overcome by adding extra resin and optimizing mixing time of materials. CCS value of samples after coking has significant improvement due to addition of antioxidant. It shows an increasing trend due to increase in B_4C and Si content in the bricks. Addition of B_4C+ Si shows an optimum value of CCS. This may contribute to achieve higher performance of bricks.

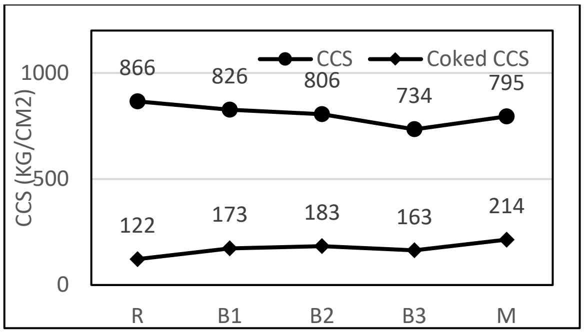

Fig.5: CCS (kg/cm^2) of as such and coked samples with B_4C antioxidants.

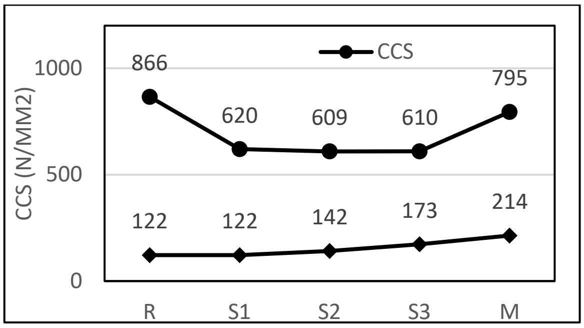

Fig.6: CCS (kg/cm^2) of as such and coked samples with Si antioxidant.

MOE value shows an increasing trend due to increasing the amount of antioxidant. It indicates that higher amount of antioxidant makes the brick more rigid and prone towards thermal spalling. So optimization was done by using combination of B_4C and Si in the bricks, which shows a moderate MOE value.

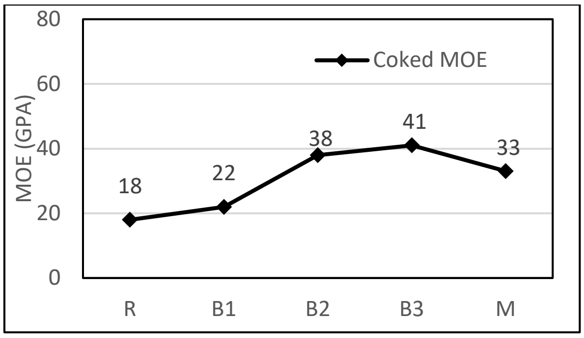

Fig.7: Coked MOE (GPa) of as such and coked samples with B_4C antioxidants.

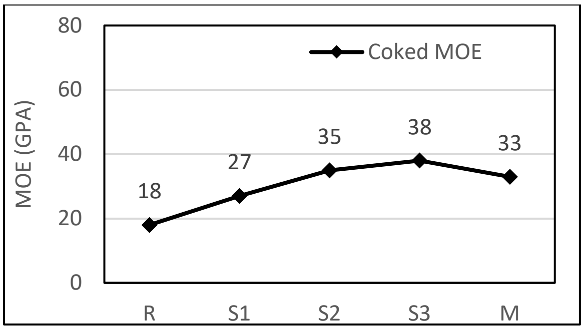

Fig.8: Coked MOE (GPa) of as such and coked samples with Si antioxidant.

It is evident in photographs showing in fig.9 and fig.10 that due to increase in antioxidant content, area of remaining black surface increases which indicates better oxidation resistance. When combination of two antioxidants (B_4C and Si) used, oxidation resistance become much better compared to single antioxidant.

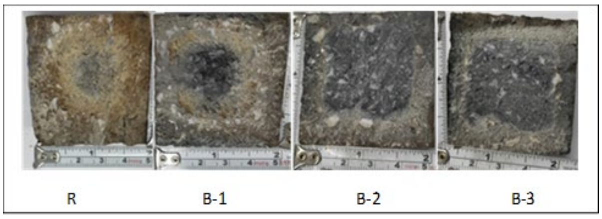

Fig.9: Oxidation test samples of without antioxidant and with B_4C added formulations.

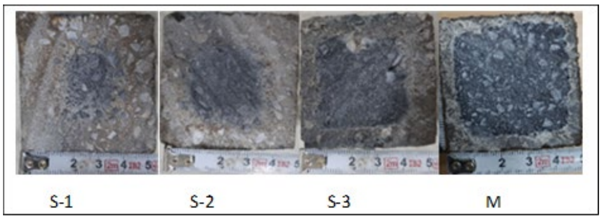

Fig.10: Oxidation test samples of B_4C added and B_4C+Si added formulations.

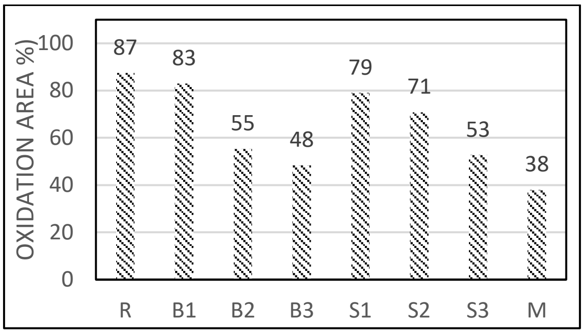

Fig.11: Oxidation area (%) of samples.

CONCLUSIONS:

Combination of two antioxidants (B_4C ++ parts and Si ** parts) in sample 'M' shows excellent oxidation resistance and moderate physical and thermo-mechanical properties in Dolo-C system compared to single antioxidant. Oxidation resistance improved due to formation of protective layers of $3CaO.B_2O_3$ and $3CaO.SiO_2$ at elevated temperature. Decrease in coked porosity and bond formation due to formation of low melting phase leads to increase in CCS value. Optimization of antioxidants has been done to balance between coked CCS, MOE value and oxidation resistance.

REFERENCES

1. A. Ghosh, S. J. (2013). The Influence of Metallic Antioxidants on some Critical Properties of Magnesia-carbon Refractories. *refractories WORLDFORUM 5 (2013) [4]*, pp. 69-74.

2. S. Jhang, N. M. (2001). Thermochemistry and microstuctures of MgO-C refractories containing various antioxidants. *Journal of the European Ceramic Society 21*, 1037-1047.

3. C. Atzenhofer, H. H. (2021). Phase formation in MgO-C refractories with different antioxidants. *Journal of the European Ceramic Society 41*, 7330-7338.

4. C. Pagliosa, N. Freire (2014). MgO-C Brick Containing Nano-boron Carbide. Refractories WORLDFORUM 6(2014) [2].