Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 06, June - 2017

Innovation in Steel Ladle Life to 157 Heats at Rourkela Steel Plant through Optimization of Refractory Material & Service Conditions

R.B. Gupta, BE (Hons.) Met. Engg., LMIIM,
Dy. Genl. Manager, Refractories SAIL,
Rourkela Steel Plant, Rourkela – 769011.
Country - India

***Abstract* - Rourkela Steel Plant (RSP) is a major integrated steel plant under Steel Authority of India Limited (SAIL) with a production capacity of 4.2 MT of crude steel & 3.99MT of finished steel. The major production of RSP comes from SMS-II i.e. from 3 nos. LD Converter of 150T capacity each equipped with three nos. state of art technology slab casters. The shop, presently making 54-60 blows per day by means of 10/11 nos. of steel ladles in operation with a fleet size of 29 steel ladles. These steel ladles are lined with Magnesia Carbon of different carbon content at different zones as working lining and transporting liquid steel from BOF's to continuous casting machine. Before transportation to CCM, secondary metallurgical treatments are conducted in ladle heating furnace and in RHOB to fine tune the composition. All ladles are fitted with porous plug through with argon purging is applied for homogenization, The steel ladle lining life plays a major role on steel melting shops productivity & quantity of the steel produced since lower ladle refractory life means higher inclusion in steel & higher cost of refractory. This paper elaborates on the performance of ladle life, including development of lining design introduction of innovative window repair concept including material development for improvement in lining to the tune of 157 heats in individual case and 129.5 heats as avg. life.**

INTRODUCTION

RSP is the first integrated steel plant in the public sector in India. This plant with 1MT capacity was set up in 1958 with German collaboration. Massive modernization of plant was carried out in the year 1996 to increase the production of cleaner steel with lower specific energy consumption, here new units like an Ore Blending Plant (OBBP), a new Steel Melting Shop with a state of art technology (SMS-II), a Sinter Plant (SP-II) and Continuous Casting Machine (slab-casters) were with state of art technology phasing out old units like Open Hearth Furnaces etc. The second modernization also completed in the year 2010-15. Now total crude steel capacity of RSP is 4.2MT and 3.9MT of Saleable steel with 2 x 16T and 3 x 150T BOF converters at SMS-I and SMS-II respectively, with a process route at SMS-I, BF → BOF → VAR/VOR → LHF → CC and at SMS-II, BF → BOF → LHF → RHOB → CC (slab). The important products worth mentioning are hot rolled coils (HRC) HR plates, Plates, CR-coils, Tin plates, electrical resistant welded (ERW) and spiral welded pipes (SWP), galvanized sheets, cold rolled non-oriented (CRNO) sheets and special plates for defense purpose.

I. REFRACTORIES FORUM

The steel ladle life is an important factor, affecting the production schedule, the quality of the steel since lower ladle life means higher inclusion in steel and the cost of production. Selection of the working lining material & its application is the key to success for steel ladles. Keeping in view the severe operating conditions, the lining material is selected to withstand, e.g. the following important parameters :

- High tap temperature (1660-1690^0) from converter
- Repetitive thermal shock on lining material
- Impact of molten steel during tapping of steel from BOF
- Abrasion with molten metal due to stirring during gas purging
- Localized heating in slag zone due to arcing in ladle furnace
- Chemical slag corrosion
- Thermo-mechanical stress on lining.

In the early stage of the stabilization of this shop, the proposed working lining pattern of 150T steel ladles was 70% alumina (HA) bricks for the metal zone and magnesia carbon (MgO-C) in slag zone, as suggested by the technology supplier. The steel ladle life during this period was around 40 heats. The procurement of the ladle refractory set was made without any performance guarantee. As the shop started picking up production, the availability of steel ladles was a major concern. It was decided to introduce MgO-C bricks replacing 70% alumina bricks in the metal zone. The payment terms were also changed from 'total set basis' to performance linked (PG) with a threshold heat guarantee basis. Reputed vendors were called to supply of MgO-C quality refractories for the working lining in the lades. Simultaneously, the in-house brick plant started manufacturing working lining MgO-C bricks for SMS-II ladle sets. This further could be extended upto 70 heats with innovative hot repair technology developed in house.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 06, June - 2017

II. IMPROVEMENT MADE OVER THE YEARS

A. *RSP* decided to increase steel ladle lining life by introducing full MgO-C bricks as the working lining and called reputed suppliers to come forward with their best technology to achieve a certain guaranteed life. Different suppliers gave their lining proposal to achieve the targeted life. The first focus was given to improve the life of functional refractories, i.e. well block (WB) for slide gate and seating block (SB) for porous plug. These blocks required changing at a life of around 40-45 heats, which in those days matched the slag zone life of steel ladles. With the improvement in the slag zone life and in order to improve the overall performance of the ladle and straight life matching with slag zone life, functional refractories were required to be procured from 45 heats to a guaranteed life of 60 heats. This had been achieved with use of zero cement castable (ZCC). ZCC is prepared by high purity alumina and grain size is optimally fixed.

B. Slag Zone

The maximum erosion takes place in the slag zone refractory because of chemical erosion of refractory along with high temperature during arcing. The inclusions are removed by the process where the inclusion comes out of liquid metal and floats above the metal level and absorbs in slag. These compounds are generally acidic in nature and highly reactive with basic refractory lining. There are enumerable methods to deactivate the acidic nature and form basic slag. One such method is the addition of lime / dolomite in the ladle during tapping to increase the CaO / SiO2 ratio in the slag. The slag zone refractory quality is improved by addition of purer quality MgO grains and addition of low ash graphite during the brick making process. The erosion of the slag zone refractory dictates the availability of steel ladles in operation.

C. Bottom

In SMS-II, the liquid steel is tapped from a 150T converter into the steel ladle from a height of around 8m. The impact of the steel on the ladle bottom causes erosion in the impact area. With the improvement in ladle life this has become an area of concern. Trials with different superior quality MgO-C with increased thickness could not solve the problem. The repair frequency of this zone increased whenever the ladle was put down for repair. This not only increased material consumption but also the repair time, affecting ladle availability in the shop. Additionally, one layer of 115mm fired chrome-magnesite.

Table 1- Properties of AMC and MC bricks for bottom impact area

Properties	AMC	MC
Bulk density / g/cm^2	3.36	3.07
App. porosity / %	3.08	2.5
Coked AP / %	6.86	11.5
Coked BD / g/cm^2	3.32	2.95
CCS / kg/cm^2	551	410
HMOR (1400^{0}C/30 mi) / kg/cm^2	82.9	37
Decarburized area / %	40	49
Decarburized thickness / mm	6.06	7.47
PLC (1600^{0}C/ 2 h) / %		
1st cycle	3.13	
2nd cycle	0.52	
3rd cycle	0.36	
4th cycle	0.21	
Total after 4 cycles	4.22	Nil

(MCH) bricks was introduced as a protection layer to over come erosion of the bottom. To hold this protection layer and also to protect the lower side wall working lining, one ring of MCH bricks of 230mm height and 115mm thickness was also laid in front of the lower most side wall. These chrome-mag bricks provided additional protection of the impact area.

Findings from the literature and trials in other plants revealed that alumina magnesia carbon (AMC) quality would be a better choice for the impact zone of the bottom lining. Developmental work and trials of AMC bricks for the bottom impact zone started and with the higher thickness in this location, the life of the bottom was increased, matching the metal zone life. The typical properties of AMC for the bottom impact zone and MgO-C quality bricks for the side wall, as ell as rest of bottom of steel ladles are shown in Table 1.

D. Metal Zone

The refractory lining in this zone, i.e. from the bottom to the metal level was felt to be important to improve the ladle lining life because the total ladle life depends on the performance of this zone. Work was carried out on the quality of MgO-C bricks by conducting various trials and analyses of wear profiles. While replacing slag zone bricks, depending upon the erosion of the bricks of the upper metal zone, one or part of the brick rings were replaced by new ones, there was no other method to repair this zone. Initial trials with 5% C MgO-C bricks could not achieve higher life.

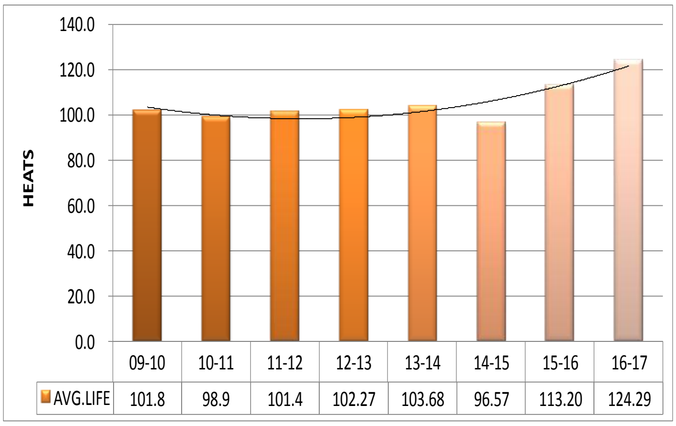


Fig 1 – Performance of ladle life

III. IN-HOUSE BRICKS

In-house development was carried out simultaneously to increase the lining life of steel ladle at SMS-II so that the specific cost and consumption of Refractories were reduced remarkably. Various developmental steps have been taken over the years jointly by Refractories Engineering (Services) department, in-house brick manufacturing facility at lime dolomite brick plant (LDBP). The quality of lining material has been continually developed based on laboratory investigations with respect to input raw materials, trials of different compositions and the study of wear profiles of the ladles. Basic raw materials like MgO grains, graphite powder and additives wear procured based upon the laboratory investigation.

A. Magnesia

For manufacturing of magnesia carbon bricks, high purity synthetic dead burnt magnesia produced from sea -water was mainly used. However, with the availabi -lity of fused natural magn -esia from China at a compet -itive price, most seawater magnesia plants in the world have stopped production. Japan was one of the major producers of seawater magn -esia and the country had 6 companies, which produced 6.88 MT in 1974 from their 9 plants [1]. China began to produce fused magnesia in the 1960's, but the production & application of it had been very limited until the emerging and development of mag-carbon bricks in the early 1980's worldwide. In 1999 China exported 0.22 million T of fused magnesia [2]. Many reputed refractory companies have also started manufacturing magnesia carbon bricks in China. Today, both fused natural magnesia and seawater magnesia are used for manufacturing MgO-C bricks. The quality of MgO grains used for manufacturing in-house MgO-C bricks is depicted in Table 2.

Table 2 : Specification of MgO used

Properties / Source	Sea water magnesia	Fused magnesia	Dead burnt natural magnesia
Chemical analysis / mass-%			
MgO, min.	97	98	96
CaO, max.	2		2.7
SiO_2, max.	0.35	0.6	0.8
Fe_2O_3, max.	0.2	0.5	0.5
Al_2O_3, max.	0.12	0.3	-
B_2O_3, max.	0.03	-	0.001
CaO/SIo_2, ratio, min.		2	2.5
Bulk density / g/cm^3	3.4	3.5	3.4
Avg. crystal size in mass-%	100	400	100
+25mm	Nil	Graded	40mm max.
+12mm	35		
+6mm	80		
-1.0mm			10 max.
-0.5mm	2		

B. Graphite

The carbon component of MgO-C bricks as a dominating effect on many brick properties. Premium quality products invariably contain flake graphite and not 'amorphous' carbon. Flake graphite particles resemble a flat plate and are distinguished by a high degree of crystalinity, which gives it better thermal conductivity and oxidation resistance compared to other forms of carbon. This particular property enhances the spalling characteristics of MgO-C composites. Corrosion test conducted in high frequency induction furnace at 1700 ±25^{0}C by Horio et al.[3] and found that higher the graphite purity, more remarkable is the improvement in the corrosion resistance. Nauruse [4] reported that with graphite of 0.7, 3.6 and 7.9 mass-% ash content, corrosion index were 72, 80 and 100 respectively when tested with a slag having CaO / $SiO_2$of 3.3 and total Fe of 13.3%. The properties of graphite being added in the bricks are shown in Table 3.

Table 3 : Specification of graphite used

Properties	96% purity	98% purity
Fixed carbon / mass-%	96 min.	98 min.
Ash / mass-%	3.5 max.	1.5 max.
Volatile matter / %	0.5 max.	0.5 max.
Moisture / mass-%	0.5 max.	0.5 max.
Size range in mass-%		
+0.295mm	20 max.	20 max.
-0.295 +0.211mm	60 min.	60 min.
-0.211mm	20 max.	20 max.

C. Antioxidants

In order to suppress the oxidation of the carbon available in bricks metallic powders are generally added to MgO-C bricks. Addition of aluminum powder also improves the high temperature mechanical strength under load. It has also been reported that aluminum addition is effective on gas oxidation. At RSP, aluminum powder as antioxidant is added for slag zone bricks and metal zone ones as well.

D. Experimental and discussion

The development was a continuous process. As such MgO-C bricks manufactured in house at the Lime Dolomite Brick Plant (LDBP) of RSP as well those as procured from outside sources have been experimented on in the SMS-II shop over the years. The performance of the steel ladle life has been discussed here based on the actual life achieved since 2009-2010 to 2016-2017 as shown Fig. 1. The Refractories for ladle bricks were procured on a performance guarantee basis from 3 reputed suppliers. Simultaneously, an in-house brick were also tried as per the lining design adopted by Refractory Engineering (Service) department of RSP, suiting the mould available in LDBP shop. The performance of the overall steel ladle life during 2009-2010 to 2016-2017 has increased to around 128 heats. As sown in Fig. 2 ladle supplier wise performance of the first repair and the final ladle life is depicted in Fig. 1. The number of ladle sets used during the year is also indicated in parenthesis. Three suppliers bricks were used during 2010-2011 and continued to till now. The current performance (monthly) after introduction of innovative window repair technique has been shown in Fig. no. 4.

Fig. 2 Performance of In-house ladle life

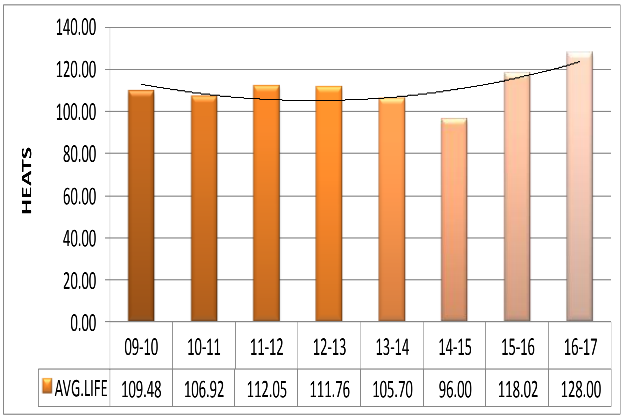


Fig. 3 Performance of Supplier ladle life

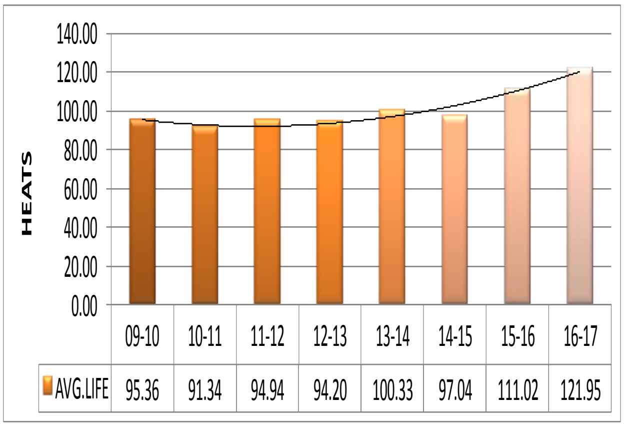
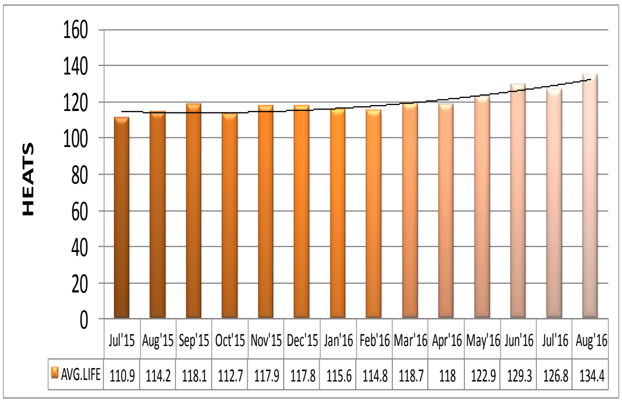


Fig.4 Current Performance of 150 MT Steel ladle at RSP



E. Present practices

Owing to the installation of second & third ladle heating furnace & RHOB in the shop, the metallurgical load on CCM-II ladles has increased to a large extent. The erosion in the purging side and slag zone side has increased remarkably. In view of the above and the experimental results of LDBP bricks, the following lining configuration adopted recently :

- Use of DBM quality MgO grains replacing SWM quality as a cost reduction measure.
- Bottom bricks with 5% carbon MgO-C bricks 230mm thick and 230mm AMC bricks in impact area
- Protection layer on the bottom as practiced earlier of chrome-mag 115mm
- Medium carbon (7%) quality MgO-C with 0.8% Al in metal zone bricks
- In the slag zone, 9% C MgO-C bricks and addition of about 2.5% Al in more vulnerable areas

The lining pattern is shown in Fig. 5 & development of lining pattern till now in Fig. 6. The refractory lining system consists of a double layer safety lining of 30% Al_2O_3 quality (40mm thick) on the bottom and sidewall. Ceramic fibre insulation paper / board is provided between the safety bricks to stop heat loss and facilitate removal after the campaign life of the steel ladle.

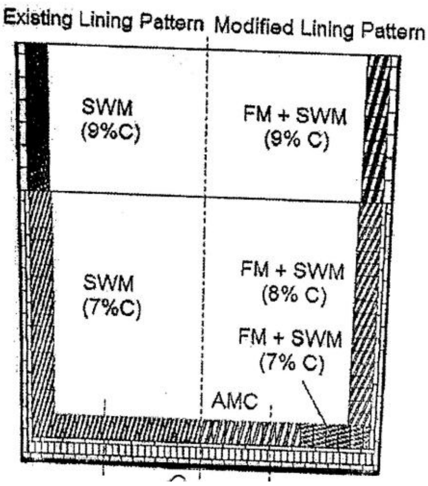
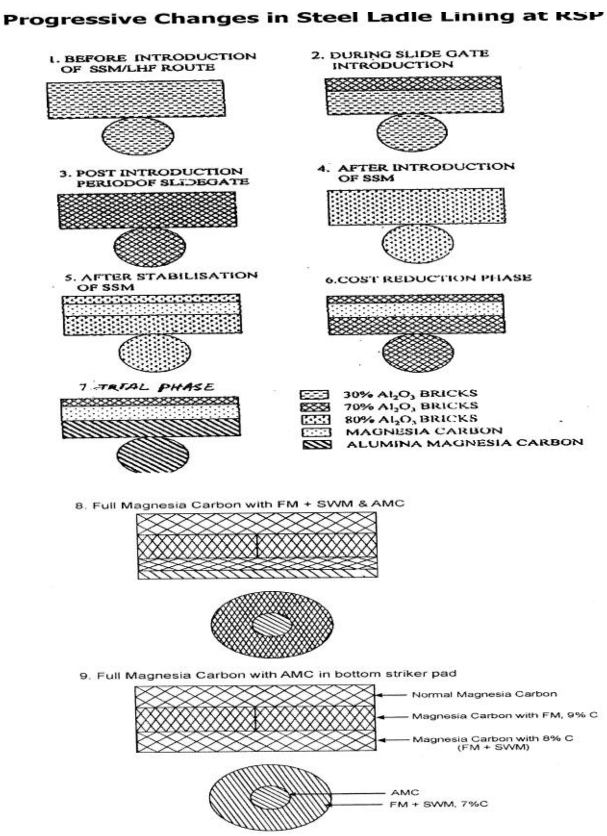


Fig.5 Techno-economically final zonal lining pattern

Fig.6



International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 06, June - 2017

F. Results

With the above lining pattern with in-house MgO-C bricks CCM-II ladle lining life has achieved a record life of 157 heats. The use of DBM quality MgO grains has substantially reduced the cost of bricks. RSP has decided to use DBM grains in CCM-II ladles on a regular basis. In 2016-17 the average LDBP ladle life increased to 128 heats. The average monthly life of a steel ladle at SMS-II is more or less stable with LDBP bricks. As a result, the specific ladle refractory consumption at SMS-II reached a level of 3.2 Kg/TCS till August' 2016.

G. CONCLUSIONS

The continual improvement made over the years in CCM-II ladles has resulted in increased ladle availability to cater to the higher production trend in SMS-II, RSP. By increasing CCM-II ladle life, RSP has substantially reduced specific cost and consumption during 2011 to 2016-2017.

REFERENCES :

[1] Akira Yoshida : Taikabutsu Overseas 25 (2005) [2] 89-99
[2] Liu. H. : China's Refractories 11 (2002) 26-31
[3] Horio T., Fukuoka. H., Asano K. : Taikabutsu Overseas 6 (1986) [1] 11
[4] Nuaruse Y. : Trans. ISIJ 24 (1984) 783
[5] Tamura S. et al. : Taikabutsu Overseas 30 (4), 275 (2010)
[6] Tanaka M. et al. : Proc. UNITECR2011 Congress Kyoto, Japan, 2011-11, 2-E-18
[7] Ikemoto T. : Carbon containing Refractories 1st Edition, Okayama, Okayama Ceramics Research Foundatio, 2006, p. 156
[8] Ogata K. et al. : Krosaki Harima Technical Report, 152, 24 (2004)
[9] Sato Y. et al. : Proc. UNITECR2011 Congress Kyoto, Japan 2011-11, 2-A-14
[10] Endoh R. et al. : Taikabutso 63 (3), 123 (2011)
[11] Chen Y. : Brooks G.A. : IGHTINGALW SA. Slag line dossolution of MgO refractory, Canadian Metallurgical Quarterly, v. 44, n, 3, p. 323-30-2005
[12] Jansson S. : Brabie V. : Bohlin L. : Corrosion mechanism and kinetic behaviour of refractory materials in contact with CaO-Al_2O_3-MgO-SiO_2 slags. In : INTERNATIONAL CONFERENCE ON MOPLTEN SLAGS FLUXES AND SALTS, 7., 2004, Cape Town, South Africa, Proceedings … Marshalltown : The South African Institute of Mining and Metallurgy, 2004. P. 341-7.
[13] Akkurt S. : Leigh H.D. : Corrosion of MgO-C ladle refractories, Americal Ceramic Society, Bulletin, v. 82, n. 5, p. 32-40, 2003