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STUDY ON LONG CAMPAIGN LIFE OF BLAST FURNACE HEARTH[1]

Zou Zhong-ping[2]
Guo Xianzhen[3]

Abstract

The present paper makes comprehensive elaboration on the long life of blast furnace (BF) hearth from the perspective of key factors to hearth design and corrosion and heat transfer system. Such analyses point out that the important control aspects on BF service life will be design, construction, dry-out, blow-in process, operational stability and maintenance management. To effectively prevent and eliminate air gap will hinge so much on expanding hearth life under the proper hearth cooling system and structure. Specifically, in design, complete measures shall be made on gap prevention; in construction, every link shall be strictly controlled; in dry-off, hot water shall be used for getting higher furnace wall temperature and more evaporation; in blow-in process, due run-in time shall be considered for the new BF to ensure reliable and valid heat transfer system of hearth, all of which pursue air-gap-free operation. No matter what structure and cooling system of refractory is applied to the hearth, only through building effective heat transfer system can the slag-iron skull be formed quickly and stably so as to realize longer campaign life of furnace hearth.

Key words: Long life of BF hearth; Heat transfer system; Cooling water; Air gap; Hearth structure design.

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[2] *Iron Making Dept., CISDI Engineering Co. Ltd., Chongqing, China.*
[3] *An-Yang Iron and Steel Group Co. Ltd., Henan, China.*

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1 FOREWORD

In today's development of iron and steel industry, the campaign life of blast furnace attracts more and more attention of ironmaking engineers and producers, especially the service time of hearth. The blast furnaces built in the 21st century have even reached 20 years more service life, as longest as 28 years. But pitifully and often, the hearth is burned through at early stage of its service life. The operator may complain about the over-heated hearth temperature even if not long after startup. Some furnaces would have to be revamped in 3~5 years after startup due to hearth problem. Such issues in practice lead to the thinking on why the hearth can be approached for longer life, and why the hearth is burned through in not long time after startup, and how to realize long life of hearth. The present paper will make the study on the long life of hearth from the systematic perspective in pursuit of reasonable and balanced solutions.
Being system engineering, the service life of BF hearth shall be considered in hearth structural design, construction, dry-out, blow-in and production maintenance, every of which is interlinked and equally emphasized; once one of them is inconsiderate or unduly treated, the hearth would be problematic so as to fail the long-life efforts. It's never wise to merely complete one link to the most while make other links out of control. Correct way is to understand and dispose the hearth life as a whole block, learning from the lessons of BF-related issues, and to perform due measures in every link; the target of extend campaign life of blast furnace can be attained.

1.1 Structural Design of BF Hearth

1.1.1 Hearth collapse mechanism

The BF hearth is collapsed mainly from mechanical and chemical erosions, including such factors as high temperature, thermal stress, alkali metal erosion, permeation of hot metal in carbon block, oxidative attack of carbon block, design and construction, operation and maintenance [1].
The thermo-mechanical erosion mechanism is described as: stress cracking, scaling, and molten metal penetrating into the pore of carbon block, carbon block solved and washing erosion. Study shows that the thermal stress will mainly cause ring shake of carbon block. In this sense, how to reduce thermal stress can be one of effective measures to achieve long life of hearth.
The chemical erosion mechanism is described as: Alkali and Zinc begin erosion from about 400°C, taking on exponential increase with the temperature rise; oxidative erosion needs activation energy, occurring above the starting temperature, for instance, steam at about 700°C as oxidation temperature, carbon deposit and steam and hydrogen at about 450~650°C as catalysis temperature [2]. Please refer to table 1 for the critical reaction temperature of typical chemical erosion of carbon block.

Table 1. Critical Reaction Temperature of Typical Chemical Erosion of Carbon Block

Erosion Mechanism	Grade of Carbon Block	Critical Reaction Temperature °C	Upper Limit Temperature °C
Hot Metal Erosion	Full	1,150	None
Alkali Metal/Zinc	Full	870	1100
CO Erosion	High-Fe	450	750
	Low-Fe	650	750
Steam Oxidation	Carbon and Semi-graphite Brick	450	None
	Graphite Brick	500	None

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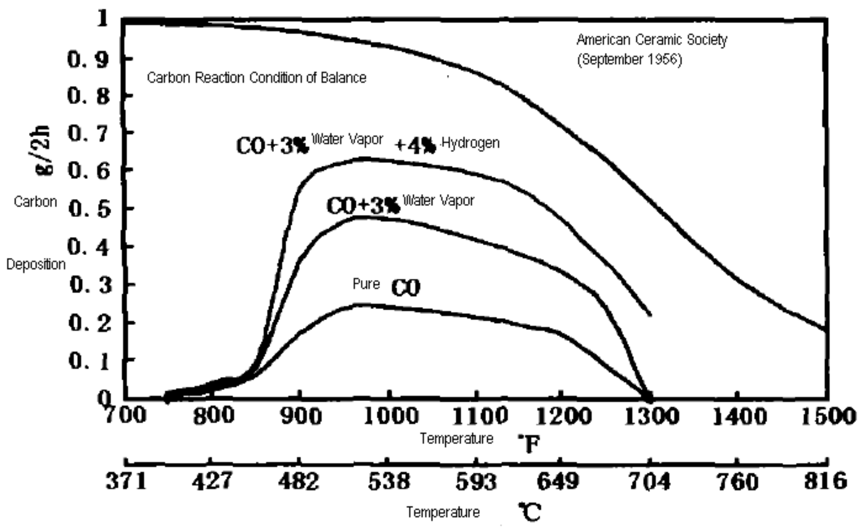

Fig. 1 Effect of temperature on relative rate of carbondeposition and accelerating effect of water vapor and hydrogen.[2]

Figure 1 gives the typical curve of carbon deposition test from exposed Al_2O_3 refractory to CO at different temperatures.

Carbon happens deposition at 450°C as well as crack and powdering in material. The deposited carbon will be expanded in the gap so that it can lead to crack between particles. Carbon deposition is regarded as one of the most significant mechanism in forming the crisp zone.

Still, carbon deposition will concentrate between hot face of carbon block and slag-iron skull, to a certain degree, which may let the slag-iron skull lose adhesion and fall off. Dissection of Meishan Steel BF in China and Hoogoven Ijmuiden BF in Holland [3]was found out that a large number of carbon deposits had been existent in the gap between carbon block and slag-iron skull. The air gap makes gas and steam pass through in the furnace wall, depositing the carbon at the interface between skull and brick. It's one of the severest threats on hearth service life. Therefore, to eliminate the air gap and water leakage from hearth has become key to longer hearth life.

1.2 Case Study and Reason Analysis of Hearth Accident

One blast furnace started up in 1998 was constructed with Chinese micropore carbon block and ceramic cup for hearth. The cooling water system had inlet pressure of 0.65MPa and inlet temperature of 42~45°C. The hearth temperature increased continuously since 2004; the 2nd row of hearth cooling stave reached the peak 224°C, and even 280°C in short time; some part of furnace shell reached 180.9°C. All these indicated serious erosion of “elephant foot” in hearth. The reasons were analyzed as: 1) carbon blocks damaged by taphole exploding which were used to solve hearth frozen problem; 2) failed to immediately change the leaked tuyeres, so that water entered to oxidize the carbon block; 3) short tuyere and low blowing energy which deteriorated the circulation of hot metal; 4) unreasonable structure of hearth; 5) over-high content of K, Na, Zn and other harmful elements to deteriorate chemical erosion.

Another large-sized blast furnace happened burnout of hearth in less than 3 years from startup, as seen 2x0.5m hole at 2.2m under its No.4 taphole.

The main reasons for the accident are analyzed as below:

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- Molten iron entered the brick slot as detected in the remnant brick: slot of brick had been built rather bigger than expected, so that the mortar was solved by hot metal and carbon block accelerated erosion.
- Incomplete building and construction quality.
- Water leakage: Cold face of carbon block was obviously down about 20 minutes in advance as observed from the recorded temperature of burned points before accident, even worse, down to 110°C and then abruptly up. The water makeup for soft water system was averaged at 0.3~0.5m^3/h, visibly rather high value, which indicated water leakage as proved by the fallen water pipe away from cooling stave. Water leaked from copper stave for long, causing the permeable zone of carbon block oxidized and useless. It would form the “mouse-hole” erosion to burn through hearth. Water leakage was diagnosed as the biggest suspect of the accident.

Take another medium-sized blast furnace as an example. Hot metal leaking from hearth happened in 3 years and 8 months from its startup. The hearth was charged with cooling water 2,560m^3/h and flow rate 1.5m/s. Reasons of the accident are analyzed as below:

- Deficiency of brick building quality under no proper supervision and for catching up with the schedule.
- Incomplete drying-out of furnace: the dry-out time is only 80hrs including temperature rise, fall and leak inspection; large amount of drop-in and water penetration from slag holes, tapholes and grout holes to outside after startup.
- Mishandling, under-evaluation of hearth damage degree when repairing the broken thermocouple; incorrect operation method causing over-drill and hot metal bleeding.

1.3 Hearth Heat Transfer System

Whatever the structure of hearth, effective heat transfer system can form stable slag-iron skull to devote to long service life of hearth.

Following Figure 2 shows the thermal resistance of the furnace wall, calculated under the circumstance of cast-iron stave, water flow 2m/s, air gap 1.5mm between water pipe and stave wall and 0.9m-thick furnace wall refractory. Of the total thermal resistance of furnace wall, the stave’s general heat transfer resistance will be 3.4%, air gap 27.1% and slag-iron skull 9.2%. The air gap exerts remarkable influence on the thickness of hearth slag-iron skull, however, much bigger than the influence of stave onto furnace wall’s heat transfer potency.

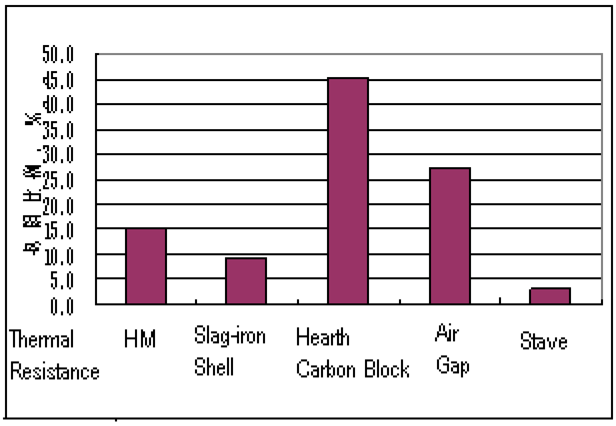

Fig. 2. Thermal resistance of furnace wall with air gap.

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Following Figure 3 shows the overall coefficient of heat transfer between hot metal and refractory at 1150°C of hot face of hearth refractory structured with different cooling types, calculated for air gaps of different thickness between stave (furnace wall) and cold side of refractory; such coefficient of heat transfer represents the intensification of hearth in furnace operation. The bigger the air gap, the smaller the heat transfer coefficient in furnace, and the closer the curves of cooling types. It means the air gap will be an important factor for hearth heat transfer. The existent air gap weakens the intensification of hearth as it withstands.

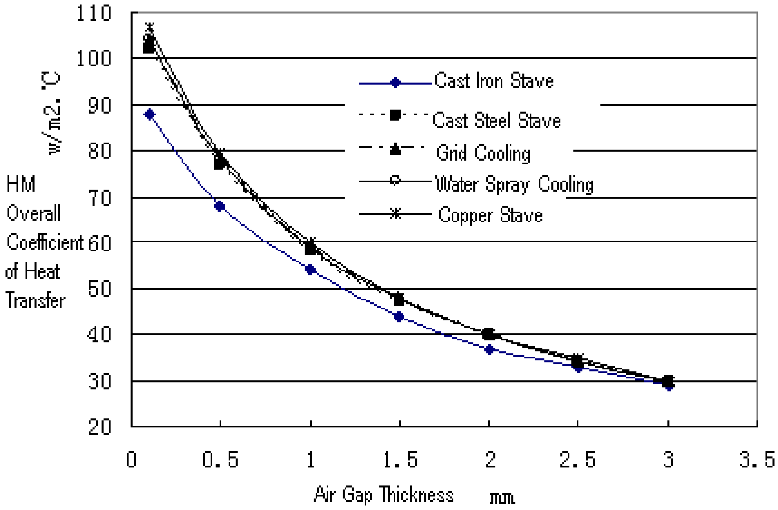

Fig. 3 Relationship between HM overall coefficient of heat transfer (in-furnace intensification) and air gap thickness.

Following Figure 4 shows the overall capacity of heat transfer reached by furnace wall at 1150°C of hot face of hearth refractory and under different heat transfer coefficients between cooling water and refractory. It's found that when the overall coefficient of heat transfer is larger than (>) 500w/m^2.°C, namely, cast steel stave, jacket cooling, water spray and copper stave cooling are used, it will not see obvious increase of the furnace wall's heat transfer capacity even though the heat transfer coefficient gets larger. However, the overall coefficient of heat transfer between the cooling water of cast iron stave and refractory is about 150w/m^2.°C, still in the range of sensitive to change. It means not ideal cooling effect performed by the cast iron stave.

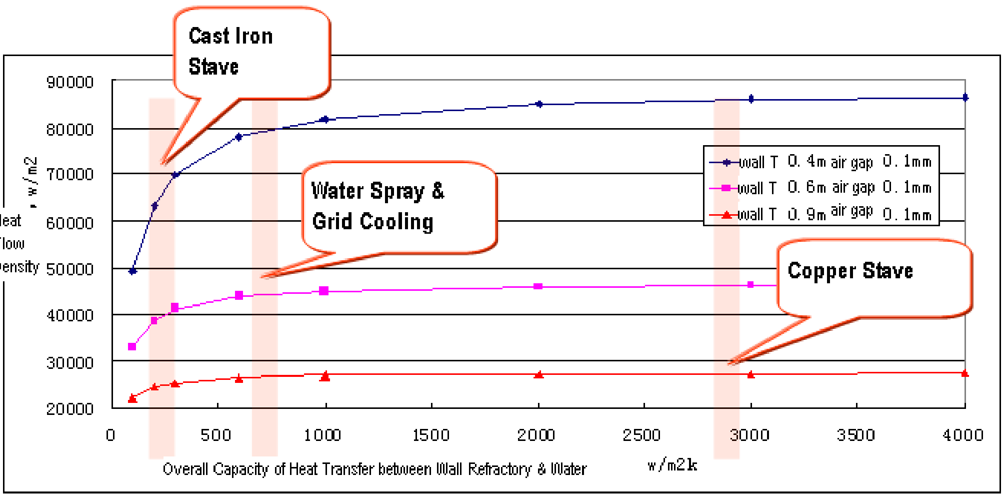

Fig. 4 Sensitivity relationship between furnace wall overall capacity of heat transfer and overall heat transfer coefficient of refractory cold face.

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The overall heat transfer of hot metal is related to furnace's intensification and stock material condition. The operation expects the most possible bigger value of heat transfer to benefit furnace running. Slag-iron skull of certain thickness to be kept on hot side of hearth refractory hinges much on ensuring hearth life. Optimization of structural design and parameters can improve the overall heat transfer capacity. It indicates the cooling measure of hearth will exert pretty impact on furnace wall's heat transfer capacity and in-furnace intensification, especially in case of not heavy wall and small air gap. Air gap of furnace wall will also influence greatly on hearth heat transfer. To that end, to select high intensity of cooling for hearth and lowest possibly-generating air gap in hearth should be emphasized in configuration.

1.4 Salamander

Some foreign studies speak of the depth of salamander. For instance, Mr. John Davidson, the British expert on BF death diagnosis, pointed out that the salamander would better 26% larger than hearth diameter. Japanese designed 5000m^3 BF with salamander 25~30% of hearth diameter. Paul Wurth suggested salamander be 26~28% of hearth diameter. China's Baosteel and WISCO calculated the salamander to be 22~23% of hearth diameter, as measured in first campaign life of Baosteel No.2 BF and WISCO No.5 BF, practical erosion depth of furnace bottom minus thickness of ceramic pad. In comparison, WISCO No.5 BF was detected shallower erosion at bottom than Baosteel No.2 BF, but more serious trend of "elephant foot" in hearth than the latter. In that sense, longer life of hearth can be helped by properly deepening salamander and bettering ceramic pad material, this way, soon forming pan bottom of furnace to release circulation in hearth and tendency of "elephant foot" erosion.

1.5 Cooling Equipment

Following Figure 5 shows the relationship between cooling water and overall heat transfer of refractory cold side under different design of hearth coolers. The result is that with the same water flow rate, cast iron stave takes lower cooling capacity than cast steel stave which is equivalent capacity to water spray and jacket cooling; copper stave takes the highest capacity among them.

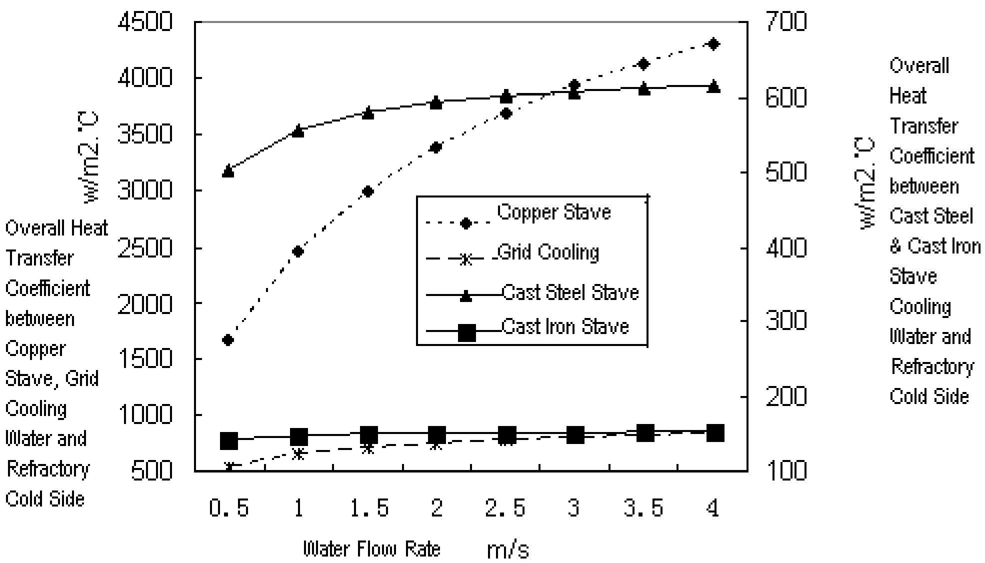

Fig. 5 Relationship between cooling water and overall heat transfer coefficient of refractory cold side.

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Analyze one by one. Cast iron stave for the BF hearth can protect the furnace shell and create benign environment, but results in low cooling efficiency, uneven cooling effect, and excessive joints between and among staves, difficult construction of filling and easy generation of air gap.

Jacket cooling can benefit the cooling efficiency, simple connection between furnace wall and shell and observation and maintenance, and prevent from generating air gap. But it may lead to direct damage of shell once in accident.

Copper stave can achieve strong intensity of cooling. But it has to have excessive joints among stave plates to lead air gap; too low temperature of refractory in front of stave is subject to collecting water leaked from hearth; copper is soft so that it may give space for air gap on hot side under the thermal load variation and external force, thus heat transfer capacity of furnace wall is impaired.

In design concerned, the proposal shall focus on less factors affecting the hearth in generating air gap, capable of getting it under control and display strong heat transfer capacity. Otherwise, cooling water system, no matter how optimized, would hardly effect if the hearth design proposal fails.

Generally speaking, jacket cooling is recommended for hearth for its adequate cooling intensity, 3 times stronger than cast iron stave. More importantly, it’s least to induce air gap, easiest to be controlled and even most possible to realize zero-air-gap hearth operation. It has been well proved by long-life blast furnaces. Anyhow, other cooling measures are not intended to be denied herein the present paper, which is just comparative comment. For any of those cooling measures, the desired cooling results can be achieved as long as every link of BF long-life chain gets controlled. Practice witnesses success of the coolers said above. This paper tries to suggest one cooling scheme with rather higher reliability through comparative study.

1.6 Cooling Water System

Above Figure 5 shows the overall heat transfer coefficient will increase with the increase of cooling water flow rate. But, the cast iron and cast steel stave and jacket cooler are less influenced by the cooling water flow rate, especially much less by 2m/s and bigger flow rate. Copper stave is more influenced; even if with small flow rate of cooling water, its heat transfer coefficient would be varied in more degree than other types of coolers. For cast steel stave, copper stave and jacket cooler, even if with small flow rate of cooling water, their heat transfer capacity would be much larger than that of cast iron stave. For cast iron stave, even if with big flow rate of cooling water, its heat transfer coefficient is increased in a bit degree, by about 150w/m^{2}K, inadequate cooling effect. Therefore, cooling type decides the range of heat transfer of cooling water; water flow rate acts not so remarkably.

BF operation tells that cooling water flow for hearth should be properly considered instead of pursuing big rate, as evidenced by the BF of longest life in the world. Give some examples. The cast iron stave for hearth of Brazil’s CST No.1 BF applies 2,000m^3/h water flow in total, serving as long as 28 years. The jacket-cooling hearth for SchwelgernNo.2 BF applies only 380m^3/h water flow, serving 18 years. The cast iron stave for hearth of Baosteel No.3 BF applies less than 1,200m^3/h water flow, serving 17 years and more. The jacket-cooler hearth for some North American BFs applies only 500m^3/h water flow, serving the best life as they can. Problems occur to the hearth with high and increasing flow rate of cooling water, temperature rise in hearth hardly restrained. In that sense, the higher water flow cannot be the ultimate solution to hearth problem.

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Following Figure 6 shows the relationship between thickness of slag-iron skull and temperature of hearth cooling water, calculated under the condition of 0.6m-thick furnace wall and 75w/m^{2}K heat transfer coefficient of HM and wall. It means the water temperature can exert limited influence on thickness of slag-iron skull.

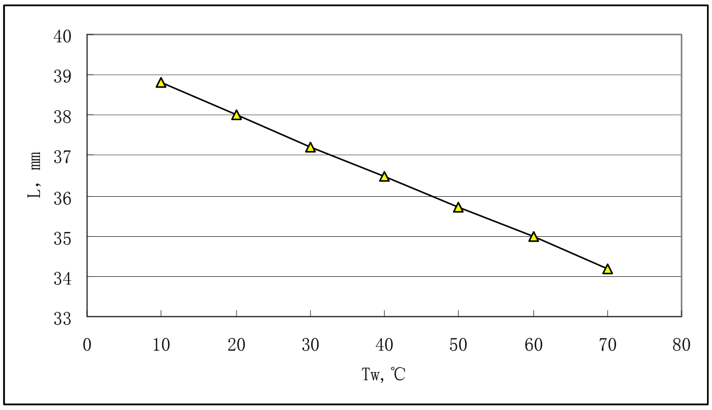

Fig. 6 Influence of water temperature on thickness of slag-iron skull.

1.7 Refractory Configuration

The BF hearth structure has to be coordinated with sound heat transfer system so that reliable slag-iron skull can be shaped quickly in pursuit of long-life furnace. Concern is carbon block of prime quality and heavy thickness for the hearth and wall could not be against the mechanical and chemical erosion of slag-iron in hearth. Only when the new thermal balance is reached and stable skull formed can the hearth be possible for longer service. Once heat transfer system is broken, accidents would take place in hearth.

In practice, thin refractory for hearth is applied, sprayed with protection layer of no more than (≤) 100mm; in furnace blow-in, the hot side of hearth refractory reaches freezing condition of early slag, which can be caught and stuck onto hearth wall; that is wonderfully conducive to furnace long life target. Attention shall be paid to give rise to slag-iron skull by production control during ramp-up period, which is effective to prepare the furnace for enough adaptability to higher output. The early slag in blow-in will be significant for the hearth withstanding complicated chemical and mechanical erosion.

Following Figure 7 shows the relationship between furnace wall thickness and protective skull thickness on wall hot side under the condition of cast iron stave and various HM and heat transfer coefficient. It indicates that the thicker the furnace wall, the thinner the skull obviously. In blow-in, slag is firstly formed in hearth; at this moment, smelting intensity is not high, accompanied with good liquid permeability of coke and impossibility of strong circulation in hearth, all of which favors fixation of early slag onto hearth wall. However, it's never wise to build thick furnace wall and protective block, unfavorable to take advantage of early slag as the protection. Thin refractory for hearth has been widely used in China's Benxi Steel No.5 BF, Meishan Steel 1000m^3 BF and North American BFs, which behave well during campaign life. To that end, skull signifies in BF service life.

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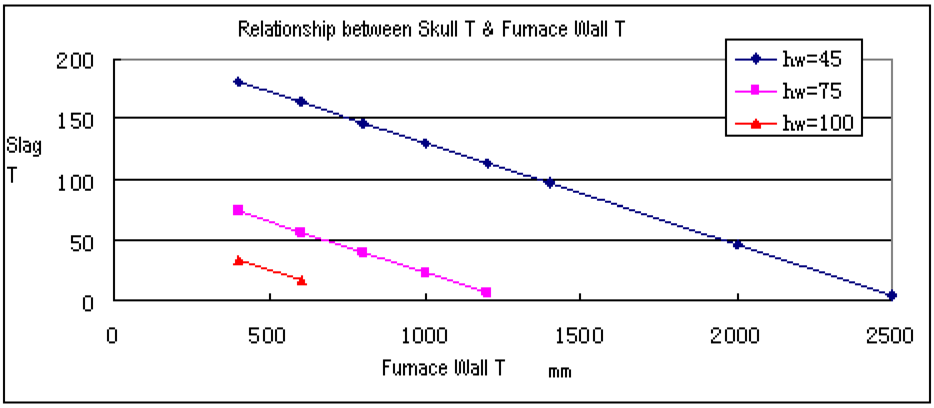

Fig. 7 Relationship between skull thickness and furnace wall thickness.

1.8 Design Concept of BF Hearth Long Life

For safe working of furnace wall in designed thickness, the maximum heat transfer quantity of hearth wall would below 100kW/m^2; meanwhile the maximum heat transfer capacity of cast iron stave would be larger than 200kW/m^2. Problem is not that cooler cannot bring away heat from hearth but the air gap arisen from leakage restrains heat transferred from wall to cooler, causing abnormal erosion of furnace wall.
In conclusion to this stage, to design a long-life BF hearth will entail relatively high water flow rate and cooling intensity, low quantity of cooling water, reasonable cooling structure and hearth refractory configuration. Such a concept ably establishes ideal heat transfer system of hearth and skull on hot face of furnace wall. Still, reasonable hearth cooling system ably guards against the existence of air gap in furnace wall. Keys to hearth life mentioned herein have to be taken care.

2 CONSTRUCTION AND DRYING-OUT

2.1 Construction of Refractory

Construction has much to do with the target of a project, through which, the design is actualized. No matter how good is the design, so has the construction of BF hearth. First, equipments of furnace wall shall be installed as per regulations, well connected stationary contact, and well sealed bolt hole and water pipe opening on furnace shell free from gas leakage. Second, building of refractory and mortar shall comply with drawing and manufacturer requirements, specifically, full mortar with no bubble and gap, against the oversize of brick seam or even triangle seam; contacts between bricks shall be closely seamed; mortar shall be forced out of the seam until proved seam size; ramming shall be packed densely. At last, refractory as built shall be cured properly against brickwork vibration or crack.

2.2 Drying-out

Drying-out is so important for hearth long life that it drains water from hearth refractory and dries the mortar and ramming material to certain strength so as to prevent gas flow after blow-in from etching the non-strength mortar and ramming material and from generating gap. During the process, the thermal energy of hot blast will be transmitted from inside to outside, meanwhile, the moisture will be driven away by the heat to the outside. The moisture remained in furnace wall will produce air gap,

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particularly, between cooling stave and refractory. The wall for hearth has to be totally dried. That is why so important to dry off by opening grouting hole and using hot water. Namely, open all the grouting holes on hearth for venting air; install water drainage pipes on bottom plate; open them to drain water and vapor during blow-in. However, it does not need to mind the mortar flown away greatly from grouting holes, which is extruded by expansion of wall refractory, will not bring about gap. Even if too much mud-jack overflows, makeup can be done for the hearth after drying-off or 1st scheduled maintenance.
Coolers for hearth shall be filled with water during drying off while pump stops. The temperature rise situation of cooling water will tell when to open pump and heat exchanger so that the refractory in front of stave can reach 110°C, the drying temperature, thus, mortar and ramming material can possess certain strength. Presently, most of the blast furnaces have not had their refractory in front of stave reach desired temperature after drying-off, large contents of moisture in ramming material remained still, and ramming material and mortar below dry-off temperature; all these would be hidden trouble for the target of long life furnace. Taphole area is seen more seriously. For the pretty thick wall at taphole and mud drum, the drying-off operation mentioned above cannot drain off moisture completely at all, remaining for sure a large amount of moisture in refractory in front of stave. In the running of furnace, moisture is evaporated, subject to generating gap between refractory and coolers; furthermore, the gap may easily gather newly-generated moisture. Thus, moisture and gas co-act to form abundant carbon deposits at hot side of refractory so as to cause peel-off of slag-iron skull, worsening erosion of furnace wall hereof, in addition to where hot metal poses intense swirling washing and erosion. It’s one of the key reasons to problem around taphole area.

3 BLOW-IN AND PRODUCTION MAINTENANCE

3.1 Blow-In

The blast furnace shall take two aspects of blow-in as highlights. One is run-in time. At the early blow-in period, ramp up of output, it’s wise and important to control production tempo to have slag-iron skull stably in hearth, which can be immune to future target production. Put it in another way, to properly control intensification process from early stage of blow-in can give the run-in time for hearth refractory so that the refractory is fully expanded and through physiochemical evolvement, laying benign foundation for hearth zero-gap operation and long service life. The other is hot-water blow-in. it’d better rise the cooling water temperature of hearth during the first one month of blow-in to have the refractory around stave reach the drying temperature 110°C; it mainly considers reducing the possibility of air gap in future normal production because the hearth is protected by refractory in at that time and it shall ensure complete drainage of moisture at cold side of furnace wall and timely consolidation of mortar and ramming material. Then it can recover the temperature of cooling water to its normal level after the one month.
Blow-in and re-blow of blast furnace shall be operated at normal pressure so that the hearth refractory is heated for expansion, and then increased pressure so that the refractory can be always tightly appressed to coolers. The expansion joint of heart refractory shall be considered elastic deformation of furnace shell to avoid gap between coolers and refractory.

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3.2 Monitor of Hearth and Concept of Long-life Operation

Following Figure 8 shows the development of furnace wall thickness below taphole and slag-iron skull thickness in 2010 operation period. It's drawn from the temperature record of long and short couples embedded in refractory. It's seen clearly hereof that sometimes slag-iron skull on hot side of refractory is rather thick, yet, sometimes disappeared so that refractory is eroded. According to the development and tendency as recorded, the operator can adjust the operation strategy, specifically, in case of rather thick slag-iron skull, the operator can keep furnace running in the status of intensification and uprising the output; in case of slag-iron skull disappeared and refractory eroded, the operator shall timely control the intensification of smelting and improve the stock condition. In particular, in the period of eroding refractory, the operator shall observe seriously what changes happen to furnace running and stock condition compared to the former period when with rather thick skull, if water leakage happens to tuyere and other coolers, and what cause gives rise to skull fading and refractory eroding. And effective measures shall be timely addressed to prevent from further erosion. Only by taking due measures can the skull be stabilized, furnace can be further intensified, and hearth can be realized longer campaign life. It's a crystal contrast to the blind operation for intensified smelting and high yield but neglecting skull fading and refractory eroding; the latter would be bound to hearth problem and furnace life failure.

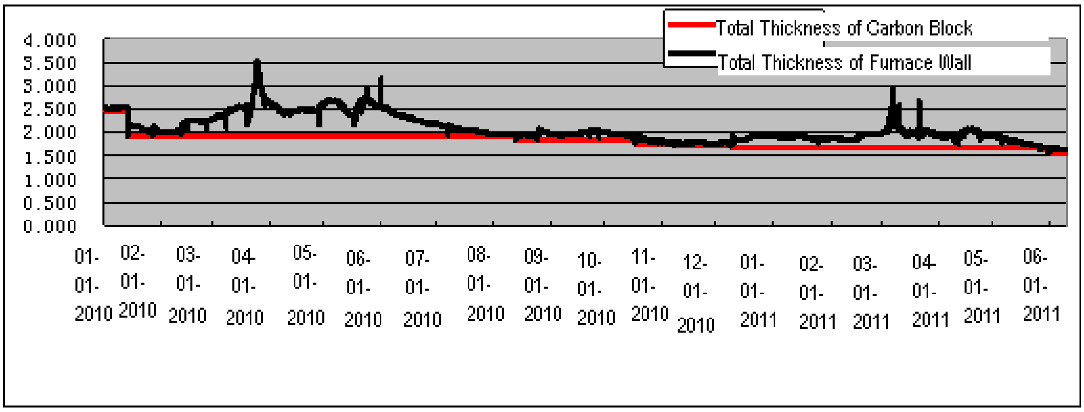

Fig. 8 Development chart of furnace wall thickness under taphole and slag-iron skull thickness.

It's suggested installing two-point thermometer for refractory at key part of hearth. Thus, erosion situation of hearth refractory can be known at all time based on the recorded temperature; then, operation strategy can be timely responded. In a word, only stable slag-iron skull can ensure a long-life blast furnace.

3.3 Maintenance of Production

For regular maintenance in early stage of BF blow-in, it'd better open the grouting hole of hearth to check the condition of gas and water drainage. And grouting activity can be done in time for hearth under strict control. The possible air gap and gas line at cold side of hearth wall can be rightly filled to achieve zero-gap during running. Grouting of hearth has to be controlled with low pressure and low flow, and installed with pressure gauge for mud jacking. The grouting prefers carbon press-in mortar with silica-solved binder so as to display its conductivity and volume stability, instead of using press-in mass of high volatility. However, in medium and later stage of furnace

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campaign when hearth refractory is severely eroded, mud jacking will be prohibited for hearth because the furnace wall becomes very thin; brickwork may be pressed loose by that weak bearing capacity. Gas shall be detected and checked from leakage during furnace running; once leaked, repair welding shall be immediately done so that gas etching can be avoided on refractory and as a result, zero gap.

Water leakage shall be also prevented from coolers, being a key to furnace service life. Investigation finds that hearth accident is mostly arisen from water leakage. Leaked tuyere shall be changed once detected, especially rendering effective management of tuyere life. Normally, tuyere will not be changed until its due date as designed. In practice, dual-cavity tuyere is an advanced measure to expand tuyere life and avert hearth water leakage, and even reduce the shutdown ratio. Take CST No.1 BF as an example. It was designed for 8-year life for the lower quality of hearth refractory; multiple measures including those mentioned above were taken; presently it has been running for 28 years. Elaborate operation and maintenance of hearth are critical to the success.

4 CONCLUSION

To stop and prevent air gap is significant for hearth long life under properly-designed hearth cooling system and configuration. Complete measures are preconditioned in design; every link of installation should be controlled, free from possibility of air gap. Temperature of furnace wall would be risen duly in drying-out to slowly evaporate moisture and solidify the mortar. Intensification process would be managed in early blow-in to give adequate time for expansion of hearth refractory, forming, drainage of remnant moisture and evolvement of bulk refractory performance; it means a run-in time for a new furnace, resulting in zero or less air gap, and guaranteeing reliable and effective heat transfer system of hearth.

Another focus on long-life furnace is reflected in reasonable configuration of hearth refractory, clear-up air gap and reliable slag-iron skull.

Incomplete drying of refractory below taphole in drying-out will have the moisture collected to generate air gap between refractory and stave, which will damage the heat transfer system; additionally, hot metal erodes the taphole area by rotary washing. All these work for the risk of accident below taphole.

The links of great importance to achieve long life BF are described as well-considered design (coolers and water system), construction quality, complete drying-off, well-controlled blow-in tempo, stable running, adjustable operation in response to thickness of slag-iron skull and well-managed hearth water free from leakage. Success in long BF hearth life has to take an integral perspective to formulate a package solution to it.

Blast furnace is granted spiritually active, similar to a human's pursuit of long life.

BF stable production like a human's healthy and regular living,

BF beneficiated burden like a human's nutritious diet,

BF cooling water system like a human's heart and vascular system,

BF wall heat transfer system like a human's strong immunity.

As I paid a visit to Schwelgern BF, I was impressed by a cartoon on the corridor wall of steelworks office building, putting the BF into a baby car, gently pushed by the director for a walk. That reflects a message of profound meaning that blast furnace, if treated like a baby with much care, cannot but grow up more stably, highly-yielding and longer campaign life.

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