Design and Simulation of Iron - Steelmaking Zero - Interface

LI Ming-yang[1] Yan Yong-gang[1] Lu Shao-wen[2] Luo Zhi-guo[2]
Shandong Province Metallurgical Engineering Co.，Ltd., Jinan 250101, Shandong[1],
China Dong Bei University, Shenyang 110004, Liaoning, china[2]
Email : goergle@sohu.com

Abstract

Base on profound study of different iron-steelmaking interface technology, designing a high efficiency, environment friendly and low consumption iron-steelmaking interface technology iron-steelmaking zero-interface technology and using computer simulation technology test, the results show that the proposal of hot iron transport system of iron-steelmaking zero-Interface technology is feasible.

Key words: One-ladle mode; iron-Steelmaking zero-interface; high efficiency ; energy conservation and environmental protection; simulation

As technology flow to produce iron and steel advances, growing importance is being attached to interface technology between steps. Particularly, the iron-steel interface between blast furnace and SMS has moved forward quite fast recently as new technologies, like locomotive carrying one ladle, electrical pallet carrying one ladle emerges. The new technologies directly affect the transmission of matter, energy and information flow between BF and SMS, associated with connecting, matching, coordinating and stabilizing steps.

It explores various types of interface technologies and put forward a new type, that is iron-steel zero interface, which primarily consists of advanced technology such as one ladle, pallet direct delivery etc, covering BF production, hot metal transport, pre-treatment, converter production etc, as well as relevant general layout.

Zero interface, or rather zero distance between BF and SMS, since there is no obvious boundary in between. It is the ultimate of technology, where efficiency, environment friendliness, energy saving features is all encompassing into one.

Existing hot metal transport pattern

Torpedo ladle car

Torpedo ladle car, as transport vehicle, receives hot metal from BF and takes it to SMS, pours into converter hot metal mixing ladle, which is lifted up to pretreatment station or charged into the converter. The equipment keeps it warm quite well, with low gravity center and good safety. BF, usually is far away from SMS, providing an enormous buffer space for good buffering. However, torpedo ladle must have one time ladle to ladle work, which leads to temperature drop in hot metal and environment pollution. Besides, ladle to ladle station would require dedusting device, calling for tremendous investment and higher operating cost.

In China, conglomerate who uses above method includes: Bao Steel (300 t). An steel (250 t), Wuhan Steel 3rd SMS (250 t) [1] etc.

Locomotive carrying one ladle transport (standard rail).

One ladle transport

One ladle straight to SMS, or rather one ladle system, has just come up as a new interface technology. It uses converter mixing ladle to receive hot metal from BF cast house, takes it to SMS for pretreatment or charges into converter. It removes ladle to ladle step by hot metal ladle or torpedo ladle car in conventional process, and uses SMS hot metal ladle for transport instead, benefitting there by due to energy saving, environment friendliness, lower production cost, etc.

Locomotive carrying one ladle

This approach uses hot metal ladle as transport container, which receives hot metal from BF, taken to SMS by diesel locomotive on rails with standard track gauge of 1435mm. With this way, BF can be arranged conventionally, but it would occupy enormous land. And for large scale converter, it might present safety risk, due to large size hot metal ladle, high gravity and narrow track gauge. Conglomerate that uses above approach includes Shougang Steel Jingtang (300t).

Pallet carrying one ladle (wide track)

With hot metal ladle as transport container, iron making and SMS are arranged adjacently. The ladle receives hot metal from BF, driven to SMS by electrical locomotive or by pallet + crane. Conglomerate that uses the above method includes Chognqing Steel (210 t), Xinyu Steel (210 t), etc. Chongqing Steel, which uses pallet + crane method / refer Figure - 1), with in between distance of about 300 m.

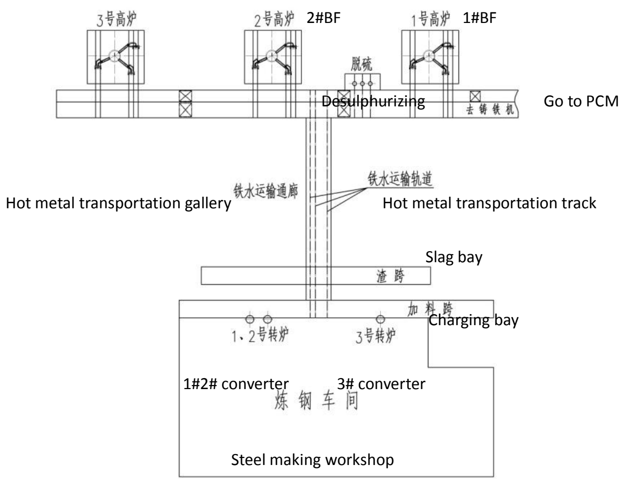

Figure - 1 : Schematic layout of hot iron car and Crane transporting hot iron of Chongqing steel

Truck carrying one ladle

With hot metal ladle as transport container, the ladle receives hot metal from BF, driven to SMS by truck. Favorably, the truck does not have to be restricted by rail turning/turnout, and track lines, flexible for GA. However, special heavy duty vehicle is required for transportation of high temperature hot metal, which is sophisticated and costly in maintenance, has high transport cost and poor safety. The approach is mostly used by small sized steel works in China, with the maximum lying in Jiangyin Xingcheng Special Steel (150 t converter).

Zero interface process design

Process layout

Taking newly built 2 sets of 5,100 m^3 BF and 4 sets of 210 t converter as object, it examines hot metal transport technology with iron-steel zero interface.

BF arrangement

2 sets of BF, adjacent to SMS, are arranged at outside slag bay, centering to the middle of SMS. BF casting line extends straight to charging bay in SMS. 4 sets of converter, 2 in a row, lie at both sides of incoming line in symmetry. Distance left in between can only cater to construction of building, or rather zero distance, see Figure - 2.

Each BF has 2 cast houses, 4 tapping holes, each hole with 2 casting lines, that is 8 tapping lines for one BF. 8 m apart tapping line, while 4.8 m apart track. Each track beneath the furnace is provided with track gauge for metering. BF taps with tilting trough, which is transported with electrical pallet, powered by cable drum. Each track is provided with 2 pallets, one working one standby.

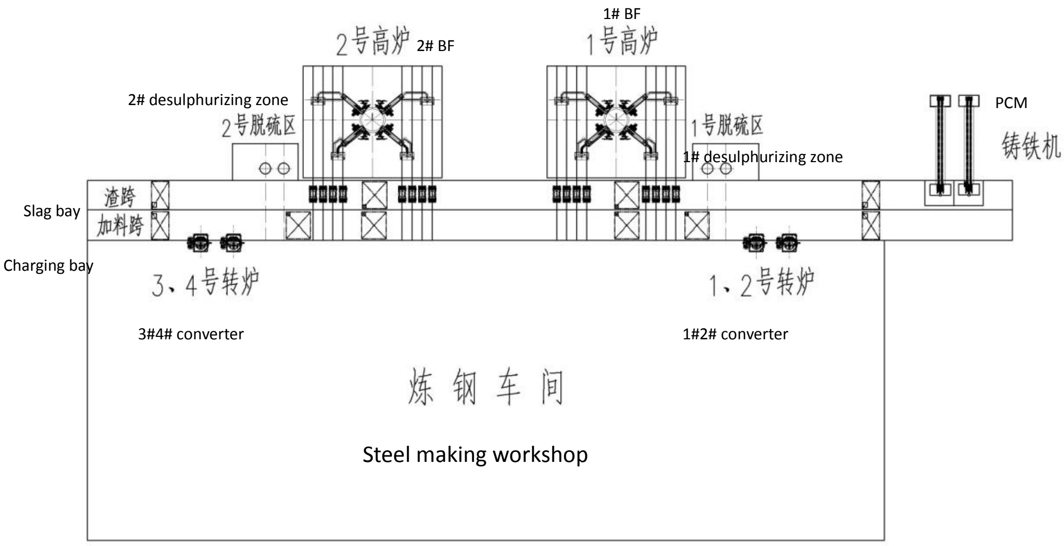

Figure - 2 : Schematic layout of Iron-steelmaking zero-interface process

Slag bay arrangement

Slag bay is arranged adjacent to SMS charging bay, with span of 24m, track surface level of +18m. Outside of each BF, adjoining the slag bay, lies 2 sets of KR hot metal desulphurization facility. At one end of the bay is provided with 2 sets of 75m PCM with hydraulic tripping method. The bay is equipped with 2 sets of 380/80t casting crane for lifting hot metal, with 2 sets of 125/40t casting crane for transfer slag. The bay also has heavy pouring ground support, emergency hot metal pit etc.

Charging bay arrangement

The bay in SMS spans 24m. BF tapping line comes through slag bay into charging bay. The bay is primarily provided with 4 sets of 380/80t casting crane for lifting and charging into converter, with 2 sets of 75+75t overhead crane for charging scrap into the converter. The scrap, having weighed on proportioning hopper in distribution center, is sent into SMS from both ends of the bay with entire hopper. The bay is also provided with heavy pouring ground support, hot metal ladle insulating heating device etc.

Iron-steel zero interface running pattern

Process flow

Under normal circumstances, when certain tapping hole is about to tap, 2 electrical pallets beneath the hole comes to position beforehand to be ready. Once it starts, the ladle at one side receives the hot metal first and swing trough moves to the other one lying at the other side, when the first one fills up. The full ladles are driven by the pallets to slag bay, where they are taken up to desulphurization tripper car by

380 / 80 t casting crane, and taken for desulphurization pretreatment. Then the pallet moves further forward to charging bay, and an empty ladle is laid on it, with new ladle it returns to BF beneath for next tapping. When pretreatment is over, it is taken by hot metal tripper car to SMS charging bay, and is lifted up by 380 / 80 t casting crane to charge into the converter. The process goes on and on until tapping finishes off. If desulphurization is not required, pallet can directly take hot metal ladle to charging bay, which is taken away by the crane there, assigned with empty ladle and returns back to BF for next tapping.

The last ladle from tapping, usually, has half of it, unfit for SMS, and can not directly be used for steel making. It could remain beneath the furnace for next tapping, or be taken to slag bay, where it is transferred by crane to next tapping hole for filling up before returning for SMS.

Figure - 3 below defects the Iron-steel zero interface hot metal transport process flow.

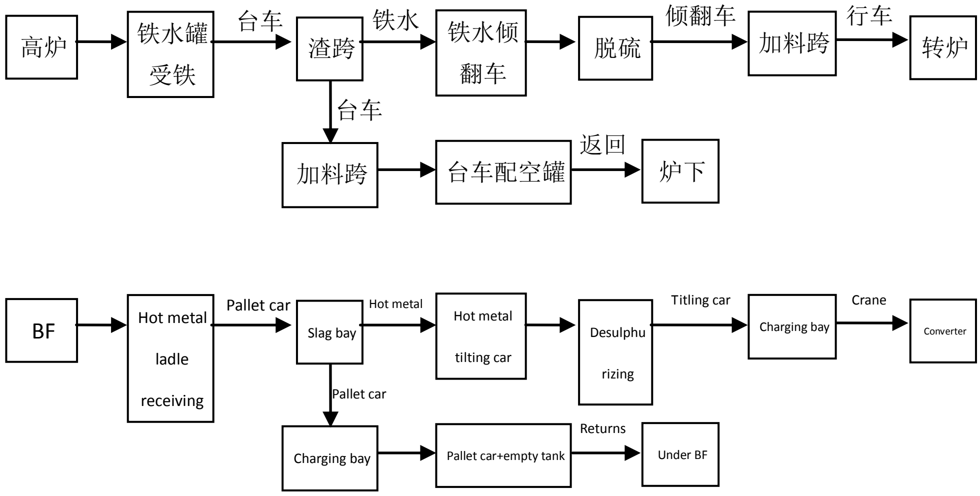

Figure - 3 : Process flow of hot iron transportation

BF tapping system

Newly built BF will have diagonal tapping system, or 3 iron runners rotate with one in maintenance for standby. Tapping time is designed to be 10～12 times/day, speed 7~9 t/min (average speed 8t/min), tapping quantity of each ladle of 210 t, max 230 t, control accuracy of ±1.0 t

Table - 1 BF tapping system

Item	Design value	Remarks
BF effective volume m^3	5100	
Average daily hot metal, t	11570	
Tapping volume/time, t	964~1157	
Tapping speed，t/min	7~9	
Tapping time/d	10~12	
Tapping duration/time	121~145	
Tapping ladle /time	4.6~5.5	
Tapping duration/ladle, min	23.3~30	Average 26.25min
Tapping system	Diagonal	

Hot metal transport pattern

It uses” one full, one away” pattern, that is once one is full, it is taken away. When hot metal is out, empty ladle must promptly be ready in position for tapping. The critical link of this process lies in prompt return of empty ladle. Supposing the ladle is filled up at one side, while the empty one does not make it back, it might spill. To ensure that, tapping cycle must be longer than transport cycle of pallet. Pallet transport cycle refers to table - 2.

Table - 2 : Transportation time of hot iron car

Item	（min） Time(min)	Remarks
Heavy ladle to slag bay	1.5 ~ 2.5	Tap hole near end to center of slag bay about 35m; hole far end to the center about 80m, electrical pallet moving speed 4~40m/min
Heavy ladle lifted away	3 ~ 4	
Pallet further forward to charging bay	1	About 24m
Empty ladle assigned	3 ~ 4	
Back to BF below for receiving	2 ~ 3	Tap hole at near end to slag bay center about 60m; far end to the center about 105m.
Total	10.5 ~ 14.5	

Table - 2 above reveals that pallet has transport cycle of 10.5 ~ 14.5 min, 14.5 min maximum, while tapping time from each ladle as said in table 1 is 23.3 ~ 30 min. Taking minimum of 23.3 min, pallet takes about 9min less than tapping time, that is 9 min as surplus or buffering time, which totally fits for process requirements.

Ladle assignment

Proper assignment of ladle is the key to zero interface technology safe production and economic running. See table - 3 for assignment.

Table - 3 ladle assignment

Item	Design value	Remarks
Receiving volume, t	211.5	
Tapping ladle per day, ladle	109.4	
Assignment pattern	One ladle one away	
Ladle cycle time, min	117	
Cycle rate, time/d	12	
No of hot cycle	10	
On line cold ladle as standby, piece	16	
Hot, cold repair and standby, piece	15	
No of hot metal ladle, piece	41	
Half ladle handling pattern	Rotate to next time or next tapping	Push into next time tapping 3rd ladle
Hot metal buffering facility	PCM, heavy ladle ground support, hot metal insulating device etc	

Simulation

The feasibility is verified by simulating iron-steel zero interface to confirm that material flow is running smooth, process viable, different links connecting or not, and that if there is any unstable or uncertain risk factor.

Simulation parameter setting

Simulation parameter is set based on design and actual production parameters, see table 4 for main values. Such parameters as converter smelting cycle, hot metal pretreatment cycle etc are generated randomly as per normal distribution, with reference to actual production. And other parameters are set according to design value.

As to the last ladle, it is to be simulated as through it goes to the next tapping hole. It has already held some amount of hot metal (to be restricted to $<$ 30t), the 3rd ladle will have tapping time 5 min less.

Table - 4 parameter values of simulation

Parameter	Valuing and instruction
BF tapping time	Ladle full=26min, last one=8min, 3rd one =21min
Converter tap to tap cycle	Normal distribution $N(40, 0.77^2)$min
Desulphurization cycle	Normal distribution $N(28, 0.84^2)$min
Electrical pallet speed	empty=30m/min , carrying capacity=20m/min
380t crane speed	empty=80m/min , carrying capacity=60m/min
75+75t crane speed	80m/min(crane for scrap)

Evasion decision model

Since there is a possibility that multiple assignments and cranes might be running simultaneously, it is likely to have competition and crane collision. The model uses priority dispatching algorithm to direct the cranes and handle assignment. Or rather it is to set up priority level based on urgency of assignment. The higher the priority is, the quicker it is served, with crane assigned in favor, and the one with less urgency is put on wait. The crane with priority can have particular area in favor of it, making those inferior wait or evade. The one with same priority uses FCFS dispatching algorithm.

Determination of priority for various assignments

Priority involves two kinds, static and dynamic: the former one is set based on importance of the work, and can not be changed once decided. The proposal can ensure highest safety and priority, followed by production and others. While the latter one is set based on running status and urgency of the work, primarily subject to static priority, assignment accomplished time, assignment tolerance time etc. Dynamic priority aims at making simulation reach closer to actual dispatching effect which is flexible in the production.

Calculation formula for dynamic priority:

$f(t) = p_t - q_t + \lambda_i \times T_{wait} - k_i \times T_{run} + \beta_j \times T_{next}$

$f(t)$ stands for assignment dynamic priority

pt for static priority of current assignment

qt for static priority of following assignment

T_{wait} for tolerance waiting time of current assignment

T_{run} for completion time of current assignment

T_{next} for time till following assignment

λ_i for weight control parameter of 0~1 of waiting time

k_i for weight control parameter of 0~1of running time

β_j for weight control parameter of 0~1of waiting time for following assignment

The above definition takes into account the static priority of current assignment, and virtually foresees the urgency of following assignment, so that the priority could be determined in a comprehensive way.

Crane evasion and collision algorithm

To avoid disorganized competition and collision of cranes arranged at same zone, the model uses virtual prediction and priority competition algorithm to evade possible collision. Or rather, the right of engaging particular track at certain zones for cranes is determined by current crane status and priorities. Virtual foreseeing is capable of obtaining status of crane and track which might run in particular zone in the future, which could be used as basis to make decision about evasion and collision.

Figure - 4 : Scheduling frame of collision avoidance of crane

Realization of simulation

Based on set simulated parameter, priority algorithm and evasion & collision model, set up simulated model, using computer simulated software by windows to simulate, referring to figure 4(only extracted part simulated interface from 2 # BF).

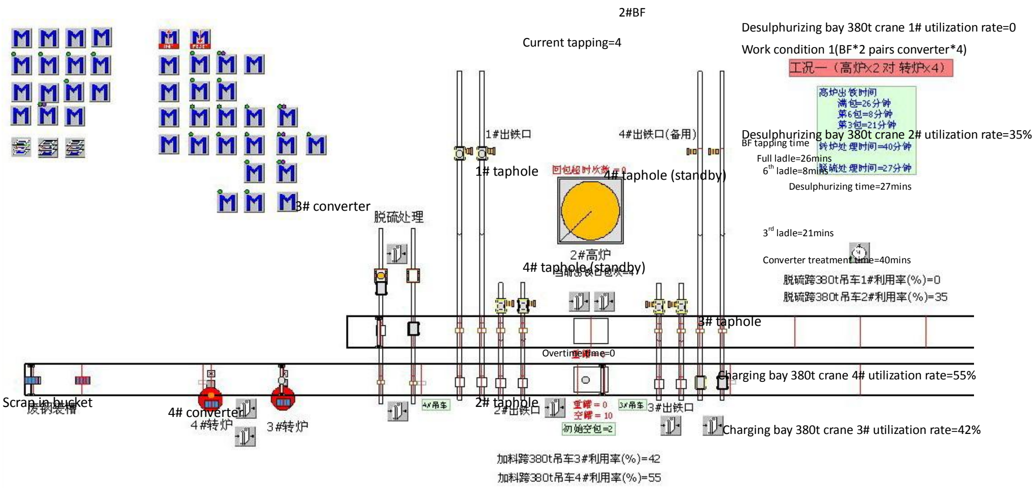

Figure - 5 : Interface of simulation system

Simulation result

According to production situation, following typical status are simulated: ①2 sets of BF and 4 sets of converter running normally; ②1 set of converter shut-down for maintenance, 2 sets of BF against 3 sets of converter under maintenance; ③2 sets of converter under maintenance, 2 sets of BF against 2 sets of converter and PCM, which is extreme emergency status; ④4 sets of converter all under phosphor removal + decarbonization duplex smelting status etc.

The result reveals that, apart from 2 sets of converter under emergency maintenance, SMS and iron making running extraordinarily unbalanced, hot metal continuing to build up, calling for BF to reduce output by back draft, it could be running smoothly under other situation. Over long time simulated running, nothing like empty ladle could not return promptly has ever happened under any situation. One and all links connect, match and run in a steady, proper and coordinated manner. It indicates that iron-steel zero interface is reasonable and viable.

Conclusion

Iron-steel zero interface technology optimizes and revamp the hot metal transport flow, taking off unnecessary links in between, simplifying process flow, and narrowing down the distance. It is a new sort of iron-steel interface technology, energy saving, environment friendly, high efficiency and simple. The technology cuts down investment and running cost, land as well. Therefore, it should bear tremendous and promising application. However, the disadvantages are that it is dependent more on ladle tapping time, that tap to tap cycle must be worked out as per particular project and that hot metal transport cycle should match. It is concluded that it should be selected and used properly.

Reference

[1] Pan Yongfei, Chen Jinfeng, Zhang Jianguo, comparison of hot metal transportation patter amongst large scale steel works, [J].BaoSteel technology ，2012，4：55~56

[2] Ye Wei, Zou Zhongping, Su Li etc, One ladle process desing for hot metal transportation in Chongqing Steel[J].iron making，2012， 31（2）：22~23

[3] Luo Shouzhang, Qiu Hongping, Liu Feng, Model setting for crane dispatching and simulation research of hot metal transportation system [J].Baosteel technology，2004， 4：18~21

[4] Long De, Me Jianshi, Xu Xinhe, Smart simulation model of hot metal transportation system, Journal of Southeastern university（ natural science edition），2005， 26（6）：523~526

[5] Cui Jianjiang, Xu Xinhe, Research of simulation system for hot metal

transportation[R].System simulated technology and application，2002， 8：48~53