The Development of Multi-Zone Model for Refining Dynamics of Decarburization and Dephosphorization in BOF Oxygen Steelmaking

Quanrong Fan 1, Yansong Shen 2, Tim Evans 3

1 QRF Consulting, Melbourne, Australia
quanrongfan@gmail.com

2 School of Chemical Engineering, University of New South Wales, Sydney, NSW 2052, Australia
ys.shen@unsw.edu.au

3 Rio Tinto, Perth, Australia
Tim.Evans@riotinto.com

ABSTRACT

Over the last several decades, there have been various dynamic steelmaking models developed to predict and control the deC and deP process in the BOF converter. The fundamental concepts used in these models are still not well described, especially phosphorus reversion during the main blowing period. This paper outlines a 6-Sites dynamic model from recent water modelling and analyses of industrial converters which aims to describe the reaction kinetics and refining phenomena occurring for deC and deP. Understanding these behaviours, including the appearance of the combustion flame, slag foaming and refining of melt droplets in the slag, the corresponding oxygen distribution, the consumption of carbon in the bulk metal and slag emulsion, and the mechanism of phosphorus removal and reversion are paramount to achieving efficient refining. An effective blowing strategy for efficient deP in the converter becomes critical as lower grade iron ore with higher phosphorus content is utilised. Only through improved technology and optimized process control, using either a single-slag or a double-slag process with separate deP and deC practices can high BOF refining efficiency be realised.

Keywords: BOF Steelmaking, Oxygen Converter, Steelmaking Dephosphorization, BOF Decarbonization

1. INTRODUCTION

The BOF oxygen steelmaking involves the fundamental subjects of pyrometallurgy, turbulent fluid-dynamic and the combustion of CO-O2. Numerous laboratory experiments and industrial investigations have been conducted to study the intervened complexity of LD-based converter, where understandings are still behind in development of the industrial converters that scale up from small-scale 30-50 t to large-scale 200-300 t converters within 20-30 years. The situation has been alleviated recently by means of extensive industrial investigations and overall clarifications of blowing dynamics. However, reliable information from the industrial-scale converters has been limited due to the difficult on-site measurements and data collection. Considerable efforts have been spent on various dynamic models to describe the blowing processes. The early version of the models captivates the jet impact area as a major reaction site where deC refinement can be modelled satisfactory with several coupled reactions and fitting parameters. However, the single zone models are inadequate to describe deP process due to constrained thermodynamic conditions.

The latest version of the multi-zone models has been developed to divide the spatial converter into several reaction zones with distinctive characteristics and mass transports, this approach is well positioned to describe the complex blowing dynamics in the converter, despite the overall descriptions have been difficult due to the chaotic fluid dynamics and coupled reactions. The transient blowing dynamics and limited sampling data also contributes to the unclear pictures of the reaction mechanism upon which the dynamic models depend heavily. With respect to the investigations of several industrial converters and water modelling of lance injection, a 6-Sites dynamic model has been built up to elucidate the refining dynamics and reaction mechanisms, including the hot spot theory to describe the carbon flame claimed to be the highest temperature inside the converter. The dominant site of the decarburization will be estimated according to the mass balance of FeO in the slag emulsion. The simultaneous deP and reP mechanism of the refining processes will be discussed for BOF converter.
2. INDUSTRIAL CONVERTER USED FOR THE DYNAMIC MODEL

The development of a 6-Sites dynamic model has been related to the quantitative analyses of several industrial converters, particularly on the basis of the explorations of a 200 t converter carried out by Cicutti et al. The bath diameter of 200 t converter is of 6 meters for the sampling apparatus inserted with a certain distance from the jet impact area to pick up the samples at seven points of the blowing time. A complete set of the sampling measurements and operating parameters can be analyzed to characterize the refining dynamics and reaction kinetics for comprehensive evaluations.

At the early stage blowing of the 200 t converter, deC refining appears to progress in parallel to the oxidation of silicon and phosphorus, the carbon content of the molten bath decreases slightly from 4.0% to 3.6% in 3.5 min with an average deC rate of 3.8 kg/s for a considerable amount of CO escaping from the bath. From blowing time of 3.6 min forward, the refining process progresses into the main blowing period of 10 min with an almost constant deC rate of 10.3 kg/s which is double of deC rate at early stage of blowing. The final stage blowing takes about 3.5 minutes and deC rate gradually slows down to the endpoint. Of the three blowing stages, the attentions have been placed on the main blowing period that is responsible for the removal of 75% of the carbon from the bath, the leading refining site of deC is estimated for this blowing stage either being in slag emulsion or the bulk bath.

3. REACTION SITES OF 6-SITES DYNAMIC MODEL

Over the last several decades, various dynamic models have been suggested by means of either a single reaction zone or multiple reaction zones. The former is generally too simple to characterize the complicated blowing dynamic inside the converter, the latter sometimes has been unsophisticated in identification and clarification, for example of slag emulsion where the top slag foam might be influenced by the melt droplets splashed into it and lower layer of slag phase by the interaction with the molten bath.

The development of a 6-Sites dynamic model has been accompanied by the identification of six reaction sites inside the converter as displayed schematically in Figure 1: (1) the jet impact site is the cavity area with a parabolic profile in the middle of the molten bath. (2) the melt emulsion is the top layer of the molten bath next to the jet impact site. (3) the lower layer of slag phase above the melt emulsion. (4) The highly expanded slag foam above the lower layer of slag phase. (5) the freeboard near the oxygen lance above the molten bath up to the converter mouth. (6) the melt bath under the jet cavity area and the melt emulsion. These 6 sites have been identified inside the converter with the slag phase subdivided into the slag foam and liquid-type slag layer, and the bulk molten bath into the jet impact area, the melt emulsion and the melt bath.

Figure 1. 6-sites dynamic model of BOF converter.
**Site 1 – Jet Impact Region**

The interaction of the oxygen jet with the melt impact site leads to the oxygen penetration into the molten bath and the splashing of droplets into the slag emulsion and the freeboard. The cavity area is unstable and unbalanced due to melt expelled and replaced by the oxygen jet under the jet impact force and buoyancy force. The chemical reactions and the physical interactions in the cavity area determine the overall blowing dynamics. This chaotic segment has received considerable attention for its splashing mechanism, reaction kinetics and the cavity structure to understand the fundamental behaviours such as the blowing modes of the cavity area as a function of jet momentum and lance height.

It has been reported of three blowing modes of the cavity area as dimpling, bubbling and penetrating. The dimpling mode is simple in cavity structure; however, the bubbling mode and penetrating mode may be explained with some differences from the latest findings of water modelling as illustrated in Figure 2.

![Three injection modes of jet impact area.](image)

**Figure 2.** Three injection modes of jet impact area.

(1) Dimpling is the cavity mode shaped at lower impact velocity when the soft jet penetrates a shallow depression with no splashing observed in Figure 3, the bath surface is wrinkled and rippled with smooth wave from the cavity area.

(2) Bubbling is formed when the jet momentum increases to the impact velocity of 10-20 m/s, a splashing is noticed with droplets teared off from the bath surface as displayed in Figure 4. It is also observed that the cavity starts to oscillate gently in vertical directions with the rhythm of the cavity moving downwards under the jet impact force and upwards by the buoyancy force. The splashing is generated from the bath when the cavity moves upwards and the gas injection still forces downwards, these two forces in opposite directions squeeze the gas from the cavity into the bubbles near the cavity edge of the bath surface to splash out.

![Dimpling mode of jet impact area.](image) ![Bubbling mode of jet impact area.](image)

**Figure 3.** Dimpling mode of jet impact area. **Figure 4.** Bubbling mode of jet impact area.
The further increase of jet momentum leads to the penetrating mode with much deeper penetration and strengthened splashing. The jet appears to push the water away and circulate inside the cavity to reach the maximum volume in the form of cavity bubble, the generated cavity bubbles oscillate horizontally according to the oscillation frequency of the bulk bath. The resonance phenomenon appears when the oscillating cavity bubbles provide buoyancy energy to the bulk bath, and the wave movement of the bath pushes the cavity bubbles away from the injection point. Strong splashing is observed at this injection mode when the cavity bubbles float upwards to the bath surface to splash in all directions as displayed in Figure 5.

![Figure 5. Penetrating mode of jet impact area.](image)

In the top-blowing steelmaking converter, the penetrating injection mode is supposed to be the case when the oxygen jet approaches the melt with the impact velocity of 100-200 m/s. It is suggested that large cavity in the shape of oxygen bubble could be formed periodically in the molten bath. It has been reported that frequency of the bath oscillation of industrial converters is about 2 Hz, and the water modelling of Figure 5 revealed that each oscillation cycle of the bulk bath was synchronized with the formation of two cavity bubbles, thus four cavity oxygen bubbles are generated per second in the molten bath of the converter, and the maximum vertical diameter of the cavity bubble is estimated to be in the range of 0.5-0.7 m in 200 t converter that is termed as the cavity penetration depth in the literature.

The high-speed oxygen jet pushes the melt away to generate the cavity bubbles with the oxygen dissolution through the interface boundary. This boundary layer between the jet cavity and the bulk bath is not fixed in the stationary shape but short-lived and periodically generated by the oxygen cavity bubbles. The oxygen penetrates and dissolves through the interface boundary in contact with the slag droplets and carbon of the melt to generate CO bubbles,

\[
[C] + (\text{Slag Droplet} - \text{FeO}) + \{O_2\} \rightarrow \{\text{CO}\}
\]  

The slag droplets in the turbulent cavity area are rapidly saturated with the oxygen for the chemical reactions, and the trajectories of the slag droplets moving around the cavity site are illustrated in Figure 6. Some of the slag droplets in the cavity area comes from the splashing-out of the slag droplets that return into the oxygen jet to be delivered into the cavity area, and rest of the slag droplets are entrained from the slag phase into the cavity area by fluid dynamics near the cavity area.

The jet impact area for the oxygen-carbon reaction has been named the principal deC site when the temperature of the cavity area is believed to be the hotspot with the highest temperature of 2200-2500 °C inside the converter. It is rational to suggest that carbon can be removed rapidly under this high temperature, however, the contemplation of the hotspot theory is that the melt temperature in the cavity area may not reach that range of 2200-2500 °C. The dimension of the impact area is around 10% of entire volume of molten bath, the melt flows and recirculates from the bulk bath into the jet impact area is estimated to be several seconds, the circulation of melt could quickly take away the heat energy and narrow the melt temperature of the impact area to the temperature of the bulk bath, the cavity area is unlikely to raise its melt temperature 700-1000 °C above the temperature of the bulk bath due to the short residence time of the melt and the higher heat conductivity of the molten iron.
Site 2 - The Melt Emulsion
The melt emulsion is the top layer of the molten melt that is emulsified with small slag droplets as displayed in Figure 1. There are two pathways for the slag droplets moving into the melt emulsion as shown in Figure 6. (1) the slag droplets are entrained from the slag phase and carried downwards into the melt emulsion by the fluid dynamics, (2) slag droplets are carried by the melt flowing from the cavity area into the melt emulsion. A certain amount of oxygen also moves from the jet cavity area into the melt emulsion. The horizontal bath oscillation helps to push and transport the oxygen, that is not consumed in the cavity area, into the melt emulsion for deC refining. The CO bubbles generated in the melt emulsion are expected to lift some melt into the slag phase as indicated by the arrows in Figure 6, there is an undistinguishable interface between the slag phase and the melt emulsion, the actual interfacial area of the slag droplets in the melt emulsion is much larger than the apparent interface of the bath diameter.

There is evidence to suggest that the melt emulsion could be about 0.4 m in deep in the industrial converter measured by special radio -wave interferometry, the technology is based on a slight change in the receiving signals when the wave goes through the interface of two layers of different characteristics [2]. The special measurement suggests that the melt emulsion could be developed broadly due to the turbulent fluid dynamics and extends from the jet cavity area towards the bath edge, the emulsified slag droplets could be well distributed in the melt emulsion and provide significant interfacial area of the slag droplets for the refinements. The amount of molten iron in the melt emulsion and cavity area may be calculated to be about 40 t in consideration of 50% of CO bubbles in 200 t converter, and the well emulsified slag droplets in the melt emulsion could have the residence time comparable to the residence time of the melt movement in the cavity area and the melt emulsion.

Site 3 - The Liquid Slag Layer
The liquid-type slag is a thin layer located above the melt emulsion. The slag, melt droplets and CO bubbles move from the melt emulsion into this liquid-type slag layer where the carbon of the droplets reacts with FeO of the slag for generation of CO bubbles. During the main blowing period, the reduced content of FeO in the liquid-type slag could lead to the drying up of this layer of slag phase, and the drying-up of this slag layer could cause the operating problems such as the heavy splashing and slopping.

Site 4 - Slag Foam
The slag foam expends impressively above the liquid-type slag as CO bubbles occupy large space in the slag foam. The fluid dynamics of the slag foam could be determined by the movement of CO bubbles generated in the slag foam and from the melt emulsion. It is generally referenced that the apparent viscosity of the slag emulsion is higher than the viscosity of the liquid slag, thus the iron droplets in the slag foam is inflexible to move and deform an interface tension between the slag and CO bubbles. The slag foam contains 30-40 wt % of melt droplets mainly with size range of 1-3 mm and each melt droplet is limited in contact with certain neighbouring volume of slag phase, therefore, the melt droplets and the slag phase are likely to have the matching residence times in the slag emulsion due to the chemical reactions in between and swelling melt droplets with reduced density.

Figure 6. Trajectories of slag droplets around the jet cavity area.
Site 5 - Combustion Zone
The combustion zone is positioned above the jet cavity area and next to the oxygen lance up to the converter mouth. This area is occupied by the supersonic oxygen jets, the gaseous CO- CO2 and melt splashing in the forms of droplets and dusts that are capable to splash high into the slag emulsion or leaving the converter. The splashed droplets and dusts are supposed to be oxidized considerabily in contact with the oxygen under the high temperature of the combustion flame that expands from the molten bath to the converter mouth. With the oxygen near the periphery of the oxygen jets and escaping oxygen from the molten bath moves into the combustion zone, the diffusion flame is expected to be ignited by the oxygen-rich gas near the oxygen lance and gaseous CO from the bulk bath as shown in Figure 7. The adiabatic combustion temperature of O2-CO is 2500 C, and the hotspot of 2200-2600 C in the converter is probably caused by this post-combustion of the diffusion flame somewhere above the bath rather than C-O reaction in the jet cavity area. It is well known that the slag emulsion is higher in temperature by 100 C above that of molten melt in the converter, the hotspot inside the converter appears next to the slag emulsion to cause its higher temperature. Had the hotspot been in the jet cavity area, the molten melt should be higher in temperature than the slag emulsion for the higher heat conductivity of the molten iron.

Site 6 - The Melt Bath
The melt bath refers to the molten iron under the jet cavity area and melt emulsion as showed in Figure 1. No chemical reactions are supposed to progress in this area of the bath except the melt circulation from the melt emulsion and into the jet cavity area. The melt circulation may be estimated by silicon oxidation at early stage blowing with the content reduced from 0.19% to 0.03% from time of 1.8 min to 3.6 min. When all the silicon carried by the melt flowing into the jet cavity area is supposed to be oxidized into the slag phase, it is estimated that the melt flow rate increases from 1-2 t/s to 5 t/s from the blowing time of 1.8 min to 3.6 min. From 3.6 min onwards is the main blowing period for stable deC refining, the melt circulation from the melt bath into the cavity area remains at about 5 t/s, with total amount of 40 t melt in the melt emulsion, the residence time of the slag droplets emulsified in the melt circulation is estimated to be around 8 s in the cavity area and melt emulsion. The melt bath contains 160 t melt for the 200 t BOF converter.

The six reaction sites are generated and coupled in interactions inside the converter as soon as the oxygen jets blowing into the melt bath, the jet impact area is positioned in the bath center for physical interactions with the neighboring five sites that determine the general blowing phenomena and refining efficiency. A comprehensive understanding of the fluid dynamics and refining mechanisms in each of these sites is prerequisites to properly define the multi-zone dynamic model of BOF converter.

4. 6-SITES DYNAMIC MODEL
Given the reaction sites induced from the findings of water modelling and investigations of industrial converters, a 6-Sites dynamic model has been developed to describe the refining dynamics, chemical reactions and mass transports of BOF converter. The individual position and linking of the sites of the dynamic model are displayed in Figure 8. The 6-Sites dynamic model approaches the quantitative assessments of the refining process with hybrid features of hypothesis and industrial measurements. The exercises of the modelling build-up have been useful to work out the dominant sites for deC, it is also possible to predict the mass transports from an unforeseen pathway and provide insights into the process dynamics and reaction
mechanism, the interactions between the cavity area and slag emulsion are found to be two-way paths with the slag droplets move from the impact area to the melt emulsion, where the slag droplets move upwards to the slag emulsion for a certain period of time and turn downwards to the melt emulsion and the cavity area to complete a circulating cycle.

Figure 8. Reaction sites and mass transports of 6-sites dynamic model.

4.1 DeC Mechanism of 6-Sites Dynamic Model

DeC is the important refining taking place in the converter, and the controversial issue has been the dominant site for carbon removal either in slag emulsion or the melt bath. To claim the slag emulsion as the dominant site, the prerequisite is that the large number of melt droplets should be present in the slag emulsion. It is known from the sampling measurements that the slag emulsion contains 30-40 wt% of melt droplets, about 4-5 t of melt droplets exist in the slag emulsion of 8-10 t during the main blowing period of 200 t converter. The least agreed is the residence times for these droplets reported to be from 30 s to 120 s, and mean residence time of 60 s is normally accepted for the quantitative analyses of the melt droplets in slag emulsion.

The deC of melt droplets inside the slag emulsion is related to the available amount of FeO in the slag phase. The industrial measurements from 250 t converter suggested that 70 wt% of dust and melt droplets were oxidized into FeO at early stage of blowing and 30% into FeO during the main blowing period [3]. Assuming 25% of melt droplets are oxidized into FeO and half amount of carbon of the same melt droplets are removed before splashing into the slag emulsion, the deC in the slag emulsion may be estimated by the following mass balance of FeO consumption,

\[ 25\% \times \frac{72}{56} = X \times \frac{0.5 \times (C - C_0)}{72/12} + Y \times \frac{(C - C_0)}{72/12} \]

\[ X + Y = 5000 \]

where \( X \) is the melt droplets splashed into the slag emulsion in kg/min, \( Y \) is the melt droplets carried by CO bubbles from the melt emulsion into the slag emulsion in kg/min, \( C \) is the carbon content of the bulk bath and \( C_0 \) is the carbon content of the melt droplets in the slag emulsion. From blowing time of 8.5 min to 10.5 min in 200 t converter, the \( C \) % of the bulk bath is reduced from 2 % to 1.2 %, \( C_0 \) % of the melt droplets is about 0.3%. It can be estimated that the \( X \) is about 1000 kg/min and \( Y \) is 4000 kg/min. Thus, the slag emulsion is responsible for 10-20 % of carbon removing and 80-90% of deC takes place in the jet cavity area and melt emulsion, where the refining rate of carbon may be expressed by the interfacial area of the slag droplets and mass transfer of carbon in the interface boundary,

\[ \frac{dm}{dt} = k A \rho C \]

where \( k \) is mass transfer coefficient of carbon in the melt, \( A \) is the interfacial area of the slag droplets for the refining, \( \rho \) is the density of the melt, \( C \) is the concentration of carbon assumed to be 1.0 % at the interfacial boundary. The mass transfer coefficient of \( k \) may be written by following equation [4],

\[ k = 2 \times \sqrt{\frac{D}{\pi t}} \]
where $D$ is the diffusion coefficient of $6 \times 10^{-9}$ m$^2$/s of carbon in molten iron [5], $t$ is the residence time of 8 s for the slag droplets in the cavity area and the melt emulsion, therefore, $k$ is calculated to be $0.3 \times 10^{-4}$ m/s. For 90% of deC taking place in the cavity area and melt emulsion, the corresponding interfacial area of the slag droplets in these two sites can be estimated to be 5000 m$^2$ from Equation 4.

With circulation of slag droplets from the cavity area to the melt emulsion where the slag droplets move up into the slag emulsion for a certain period of time and back into the cavity area, the slag circulation rate may be expressed,

$$W = R T_1 + R T_2$$  \hspace{1cm} (6)

where $W$ is the slag amount of 10 t in 200 t converter during the main blowing period, $R$ is the slag circulation rate of kg/s, $T_1$ is the residence time of 8 s for the slag droplets in the cavity area and melt emulsion, $T_2$ is the residence time of the slag in the slag emulsion of 60 s, the slag circulation rate could be estimated to be 150 kg/s. Given the slag circulation rate and the total interfacial area of 5000 m$^2$ of slag droplets in the cavity area and melt emulsion, the average size of the slag droplets emulsified into the molten iron is around 0.5 mm. The 80-90% of deC refining in the cavity area and the melt emulsion is due to the large interfacial area of the emulsified slag droplets, nearly 200 times larger than the apparent interface of the slag phase and the melt bath of 200 t converter.

4.2 DeP Mechanism of 6-Sites Dynamic Model

The deP refining progresses rapidly at early stage of blowing with phosphorus contents of the bulk bath reduced from 0.065% to 0.035% from 1.8 min to 3.6 min, it is also noticed that the phosphorus reversion takes place with phosphorus content increasing in the bulk bath from 5 min to 9 min. This phenomenon suggests that both deP and reP of the bulk melt progress simultaneously with deC, it is also feasible that deP and reP progress simultaneously somewhere inside the converter. When the slag droplets are emulsified into the cavity area, they are immediately saturated with oxygen from the oxygen injection jet, therefore, the following deP reaction progresses to form P2O5 in contact with the slag droplets,

$$[P] + \text{(Slag Droplet - FeO)} + \{O_2\} \rightarrow \text{(Slag Droplet - P2O5)}$$  \hspace{1cm} (7)

This deP refining with the slag droplets continues when the slag droplets move from the cavity area into the melt emulsion until the point where the deP is terminated as the slag droplets approach the balanced thermodynamics of phosphorus partition ratio and oxygen potential. From this turning point, the slag droplets move towards the bath periphery and following reP progresses with P2O5 of the slag droplets reduced by carbon of the melt,

$$\text{(Slag Droplet - P2O5)} + [C] \rightarrow [P] + CO$$  \hspace{1cm} (8)

Thus, deP proceeds in the cavity area and nearby melt emulsion, while the reP takes place simultaneously in the melt emulsion towards the bath edge. The net effect of deP and reP of the bulk bath may depend on the following equation,

$$W_d - W_r = \int_{t_i}^{t} \frac{d W_d}{d t} \Delta t - \int_{t_i}^{t} \frac{d W_r}{d t} \Delta t$$  \hspace{1cm} (9)

Where $W_d$ is the amount of phosphorus of bulk bath oxidized into the slag droplets, $W_r$ is the amount of phosphorus reduced from the slag droplets back to the bulk bath, $t_i$ is the time of the turning point for the slag droplets in the melt emulsion and $t$ is the total residence time of the slag droplets in the cavity area and the melt emulsion. At early stage blowing of 1.8 min to 3.6 min in 200 t converter, $W_d$ is larger than $W_r$, therefore this period is called de-phosphorus period and the phosphorus content of the bulk bath is reduced. During the main blowing period of 5 min to 9 min, $W_d$ is smaller than $W_r$, the blowing period is termed re-phosphorus as the phosphorus content of the bulk bath increases. From blowing time of 3.6 min to 5 min, $W_d$ is approximately equal to $W_r$ for an unchanged phosphorus content of the bulk bath, nevertheless, deP refining and reP reversion continue during this period of time and proceed simultaneously on the emulsified slag droplets in the cavity area and the melt emulsion of BOF converter.

CONCLUSIONS

With the latest findings of water modelling and spatial analyses of the industrial converters, a 6-Sites dynamic model has been developed with the molten bath being sub-divided into jet impact site, melt emulsion and the melt bath, the slag emulsion into a liquid slag layer and expanded slag foam. Several concepts and mechanisms used for a 6-Sites dynamic model are described for the following conclusions:

1. The hotspot is defined as the highest temperature area inside the converter, and the melt temperature in the jet cavity is unlikely to approach 2000-2400 C. The hotspot in BOF converter could be positioned above the cavity area where the diffusion flame of CO-O$_2$ combustion takes place, and the dimension and temperature of the flame is expected to vary at three stages of deC refining.
2. The dominant sites for deC are estimated to be in the cavity area and the melt emulsion due to the significant interfacial area of the emulsified slag droplets in mm size and responsible for 80-90% of carbon removal.
3. The melt droplets and slag circulation in the slag emulsion could have a comparable residence time of 60 s because of the coupling of the swelling melt droplets with the slag phase and CO bubbles.
4. The residence time of the emulsified slag droplets in the cavity area and the melt emulsion is about 8 s, close to the residence time of the melt circulation in the cavity area and the melt emulsion.
5. The interfacial area of the slag droplets in cavity area and melt emulsion could be around 5000 m², 200 times larger than the apparent interface of the slag phase and the melt bath of 200 t converter.
6. The lower frequency of the bath oscillation of industrial converters is about 2 Hz, and the water modelling revealed that each oscillation of the bath is synchronized with the formation of 2 cavity bubbles, about 4 cavity oxygen bubbles are generated per second in the molten bath of BOF converter, and the maximum vertical diameter of the oxygen cavity bubble is equivalent to the cavity penetration depth.
7. The deP and reP of the slag droplets takes place simultaneously inside the BOF converter, deP on the emulsified slag droplets proceeds in the cavity area and nearby melt emulsion, meanwhile, reP of the slag droplets progresses in the melt emulsion near the bath periphery.

REFERENCES