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COMPARATIVE STUDY BETWEEN TRADITIONAL AND COHERENT JET OXYGEN LANCE INTERACTION WITH MOLTEN POOL

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As an advanced nozzle and because of protective gas around the main oxygen hole, coherent jet oxygen lance can make the jet concentrated with higher kinetic energy. In this paper, a coherent jet oxygen lance is tried to be made with small oxygen holes around the main oxygen hole on the traditional oxygen lance. Flow characteristic of coherent jet oxygen lance and traditional oxygen lance are simulated by CFD software. The results show that, compared with traditional oxygen lance, the attenuation of coherent jet oxygen lance is slow on the center axis, impact depth is deep, the liquid region velocity is high in the center of molten pools, flow ability of liquid steel is good in molten pools. Coherent jet oxygen lance with the suitable lance height can replace traditional top-bottom blowing mode.

Key words: Basic oxygen furnace (BOF), stell, oxygen lance, coherent jet, oxygen flow

INTRODUCTION

Oxygen lance is the most important oxygen steelmaking equipment, with it used to produce supersonic oxygen flow that injected to the bath and completes decarburization, heating and miscellaneous reactions. In the 1990s, Praxair Company invented a new oxygen lance --- coherent jet oxygen lance [1]. Because of combustion-gas surrounding main oxygen hole, so attenuation of oxygen jet velocity decreases slowly and can be kept in long distance with the initial diameter and supersonic velocity, and provides sufficient kinetic energy to the molten pools [2]. Lots of researches have studied this technique, K. Liu and M.Y. Zhu has studied flow field of a coherent jet oxygen lance with one main oxygen hole, results showed that experimental results could be predicted better by revising k-ε turbulent mathematical model, the attenuation of the central jet in its range reduced because of a concomitance flow existence, radial and axial jet flow states were influenced by ambient temperature [3]. Numerical simulation about oxygen stream field of the coherent jet oxygen lance has been studied by Li Goofing with CFX 5,7,1 software used. The results showed that the jet flow of the coherent jet oxygen lance was long, concentrated and with slower attenuation[4]. From the water modeling of a top-blown converter steelmaking by Cain Zipping, the distributing rules of the velocity attenuation and the vertical velocity on axis of supersonic oxygen jet were obtained[5]. Coherent jet oxygen lance technology is introduced and used in EAF, which used in BOF is still needed to be studied. In this paper, a traditional oxygen lance is modified to a coherent jet oxygen lance that used in BOF, jet parameter and interaction with molten pool are simulated by using CFD software.

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NUMERICAL SIMULATION ABOUT OXYGEN LANCE JET

Physical model

Physical model studied in this paper is traditional and coherent jet oxygen lance used in BOF. The nozzle sizes of traditional oxygen lance are shown as Table1. The nozzle sizes of coherent jet oxygen lance are same as the traditional one, the diameter around main oxygen hole is 3 mm. The nozzle is discretized with finite volume method, and tetrahedral mesh form is used, meshes close to the wall are dense and close to axis are sparse. Molten pool depth is 1 200 mm, molten pool diameter is 4 000 mm and frustum height is 500 mm. To accelerate convergence and improve calculation accuracy, meshes of the nozzle and body of the converter were drawn respectively.

Talbe 1 **Oxygen lance nozzle size**

inlet diametr /mm	throat diameter /mm	outlet diameter/ mm	contraction length /mm	expansion length / mm	throat length /mm
47	36	47	43	63	4

Mathematical model establishment and boundary conditions

The study model is as Figure 1 showing. In this numerical simulation process, mathematical model such as

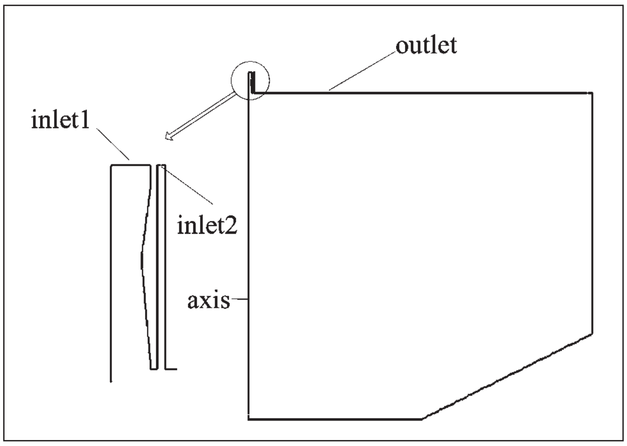


Figure 1 Boundary conditions of converter model

VOF two-phase flow, heat-transfer and realizable k-ε model were selected, with no slip wall and standard wall function, coupling, implicit method used. Pressure-inlet, pressure-outlet and axis symmetrical boundary condition were adopted in converter. On inlet of oxygen lance nozzle, oxygen pressure is 0,8 MPa, temperature is 300 K. Concomitance oxygen flow pressure is 0,2 MPa, temperature is 2 000 K. The top of the convert is set as outlet condition, with pressure of 0,103 MPa. PISO algorithm was used in coupling velocity and pressure, pressure discrete by a body force method, volume fraction discrete with QUICK method, the others discrete with first-order residual windward format. Data after calculating 2s are analyzed. Thermo-physical properties of oxygen are shown as Table 1, and the thermo-physical properties of molten steel are shown as Table 2.

Table 2 **Thermo-physical properties of oxygen**

Temperature / K	Viscosity, μ / kg · m^{-1}s^{-}	Cp / J · kg^{-1}k^{-1}	Thermal conductivity / W · m^{-1}k^{-1}
298,15	1,92×10^{-5}	919,31	2,46×10^{-2}

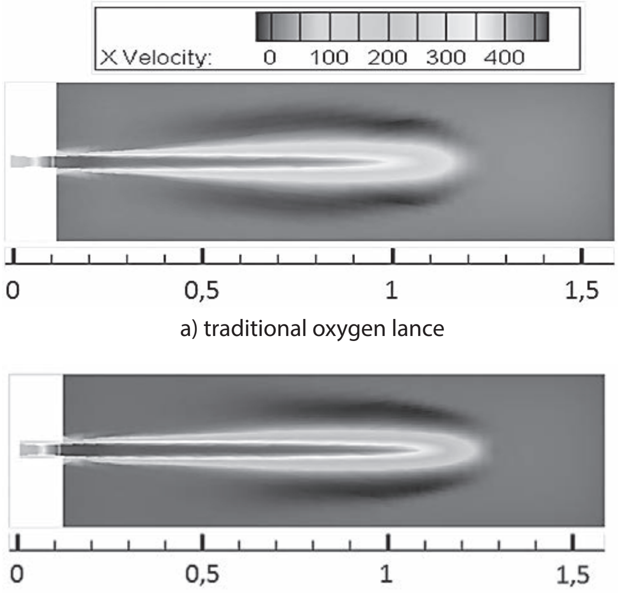
Table 3 **Thermo-physical properties of molten steel**

Temperature / K	Density, ρ / kg · m^{-3}	Viscosity, μ / kg · m^{-1}s^{-1}	Cp / J · kg^{-1}k^{-1}	Thermal conductivity / W · m^{-1}k^{-1}
1 873	7 100	6,5×10^{-3}	670	15

RESULT AND ANALYSIS OF NUMERICAL SIMULATION

Jet characteristics comparative study between traditional and coherent jet oxygen lance

Oxygen lance position affects the oxygen jet impact on molten pools, such as blowing time and the desulfurization, decarburization, dephosphorization efficiency during steelmaking. So it is critical to ensure a suitable lance height. In this paper, when the lance height is 20 de(that means 20 times of diameter of lance inlet), 30 de, 40 de, models about traditional single-hole oxygen lance and coherent jet oxygen lance in top-blown converter were established respectively. The boundary conditions were set as follows: main oxygen inlet pressure was 0,8 MPa, temperature was 300 K; pressure of 0,2 MPa and temperature of 2 000 K was used in concomitance flow inlet. Outlet was on the top of convert, with pressure of 0,103352MPa, ambient temperature was1 873 K, computing time was 2s.



a) traditional oxygen lance

b) coherent jet oxygen lance

Figure 2 Velocity distribution of oxygen jet, a) and b)

Figure 2 is the velocity distribution of the oxygen jet at 2s. Figure 2a is for traditional oxygen lance, Figure 2b is for coherent jet oxygen lance. From the flow field picture contrast, the supersonic area of the coherent jet oxygen lance is longer than that of the traditional oxygen lance.

Figure 3 shows the jet velocity distribution of the coherent jet oxygen lance and traditional oxygen lance on axis in convert model. It can be seen the velocity attenuation of the coherent jet oxygen lance is slower than that of the traditional oxygen lance at the same lance height. No matter traditional or coherent oxygen lance,

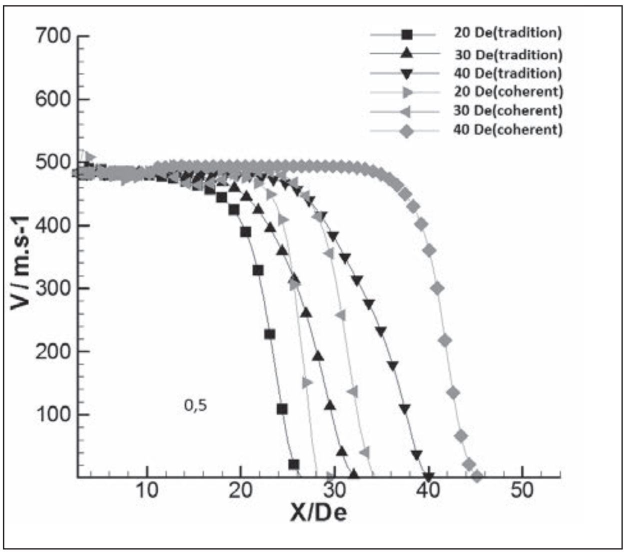


Figure 3 Velocity distribution of jet axis at different lance height

the velocity attenuation becomes slower with lance height increasing. Compared with traditional oxygen lance, coherent jet oxygen lance can keep high speed in longer distance, so its injection length is much longer and it has more power to impact molten pools.

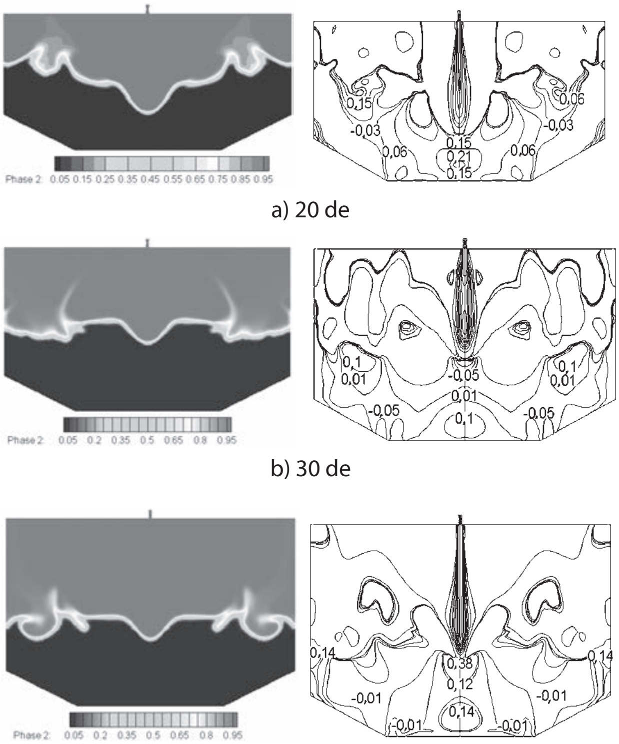
Comparative study between traditional and coherent jet oxygen lance interaction with molten pool

Traditional oxygen lance interaction with molten pool

Figure 4 shows that two-phase and velocity distributions of traditional oxygen lance injecting in top-blown converter with different lance height at 0,3s. With injection proceeding, the pit depth increases, the surface liquid steel in the center of molten pools gets enough energy to flow towards the sides. With lance height increasing, the pit depth gradually decreases, and the velocity distribution of liquid steel in molten pools differs. Velocity distribution of liquid steel demonstrates that the velocity of liquid steel in the center of molten pools is higher and that on the wall is slower at 20 de lance height, but the velocity of liquid steel on the wall is higher at 30 de and 40 de lance height.

Coherent jet oxygen lance interaction with molten pool

Figure 5 shows that two-phase and velocity distributions cloud of coherent jet oxygen lance injecting in top-blown converter with a different lance height at 0,3s. The law of coherent jet oxygen lance injecting is the same as traditional oxygen lance injecting, but with the same lance height and injection time, the impact velocity and pit depth of coherent jet oxygen lance are higher than that of traditional oxygen lance, the surface liquid steel in the center of molten pools gets enough kinetic energy to flow towards the sides of the molten pool. The internal reflux liquid steel does not reach the pit, the pit deepens, the pit depth becomes shallow gradually with the lance height increasing. The impact velocity and pit depth is higher with 20 de lance height, that of the lance height of 30de and 40 de are just the opposite, the difference of molten pool center liquid steel velocity and that near the wall is smaller.

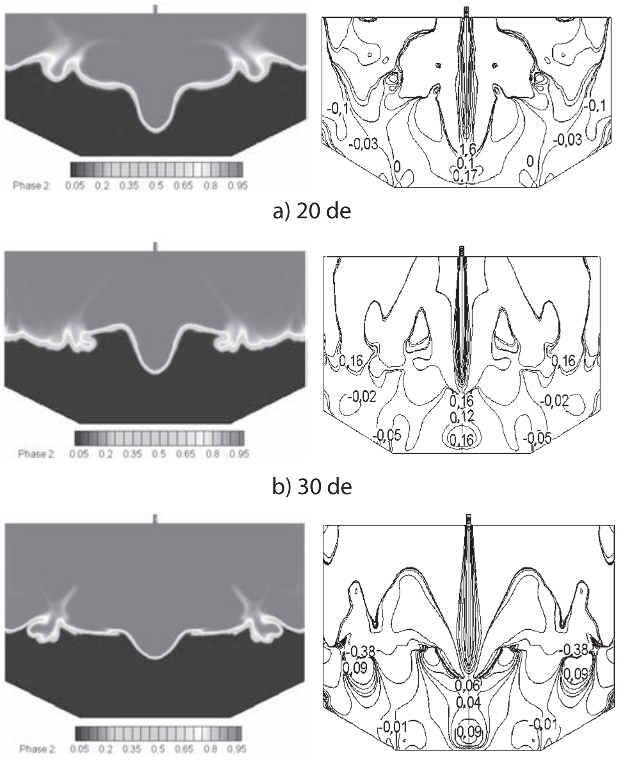


a) 20 de

b) 30 de

c) 40 de

Figure 4 Two-phase distribution cloud and velocity profile distribution of traditional oxygen lance injecting in converter, a), b) and c)



a) 20 de

b) 30 de

c) 40 de

Figure 5 Two- phase distribution cloud and velocity profile distributionof coherent jet oxygen lance injecting in converter, a), b) and c)

The influence of oxygen lance height on pit depth

Under the different oxygen lance height, the simulation data about the pit depth from 0,1s to 2,0 s are drawn in Figure 6. From the curves, to coherent jet oxygen lance, it can be known that the largest pit depth occurs at 0,3s no matter how high the oxygen lance is. To traditional oxygen lance, the largest pit depth occurs at 0,3s only under 20 de lance height, the largest pit depth occur at 0,5s under other two lance height.

When the oxygen lance height is 20 de, 30 de, 40 de respectively, to traditional oxygen lance, the ratio of maximum pit depth and depth of molten pool is 0,48, 0,32, 0,26 accordingly; to coherent jet oxygen lance, the

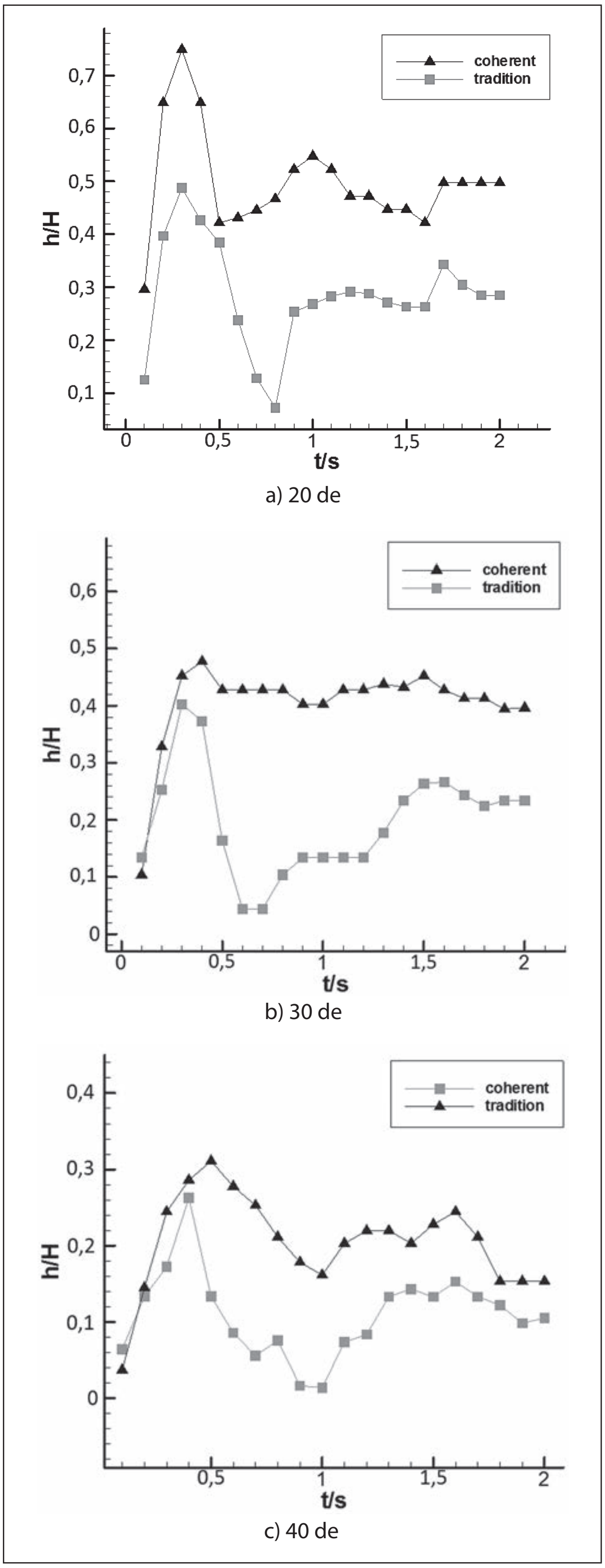


Figure 6 Pit depth change rule with time, a), b) and c)

ratio of maximum pit depth and depth of molten pool is 0,74, 0,48, 0,36 respectively, the average pit depth ratio of maximum pit depth and depth of molten pool is 0,48, 0,38, 0,28. From the comparison of the data, it can be known that the pit depth of the coherent oxygen lance under 30 de lance height is equivalent to the traditional oxygen lance under 20 de. So, with a coherent oxygen lance used in BOF, the oxygen lance height can be raised, which is useful for reduce the splash.

CONCLUSIONS

(1) The attenuation of coherent jet oxygen jet is slow on the oxygen lance central axis and the supersonic area of coherent jet oxygen lance is longer than that of traditional oxygen lance and the impact depth of molten pool is higher than that of traditional oxygen lance.
(2) With a lance height increasing, the attenuation of jet is not obvious and the trends of the attenuation at the instant contacting liquid steel are similar. The velocity of liquid steel at same position in the molten pool is decreased with the lance height increasing.
(3) The law of coherent jet oxygen lance on molten pools is the same as traditional oxygen lance, but with the same lance height, the impact velocity and depth of coherent jet are much more obvious than that of the latter.
(4) Compared with a traditional oxygen lance, a coherent oxygen lance used in BOF, the oxygen lance height can be raised, which is useful for reduce the splash.

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Note: Responsible for English language is Lector from University Anshan, China.