behavior in the simulated high temperature melts are shown in Figure 2. When the diameter of gas bubble is 3 mm, it reaches the surface after 0.9 s, the average speed is 0.283 m/s. The change of the bubble shape is small, and it almost keeps spherical (Figure 2A). When the gas diameter is 4 mm, the bubble reaches the surface after 0.86 s, the average speed is 0.297 m/s (Figure 2B). When the gas diameter is 5 mm, the bubble reaches the surface after 0.85 s, the average speed is 0.3 m/s. The change of the bubble shape is obvious, and it gradually becomes flat (Figure 2C). When the gas diameter is 6 mm, the bubble reaches the surface after 0.84 s, the average speed is 0.304 m/s. In the process of bubble rising, the deformation of bubble is very intense, and it rolls up constantly (Figure 2D). The bubble rising time decreases with the increase of initial bubble diameter, and the average velocity increases with the increase of the bubble size (Table 2). Thus, the larger the diameter of the bubble is, the greater the shape changes.

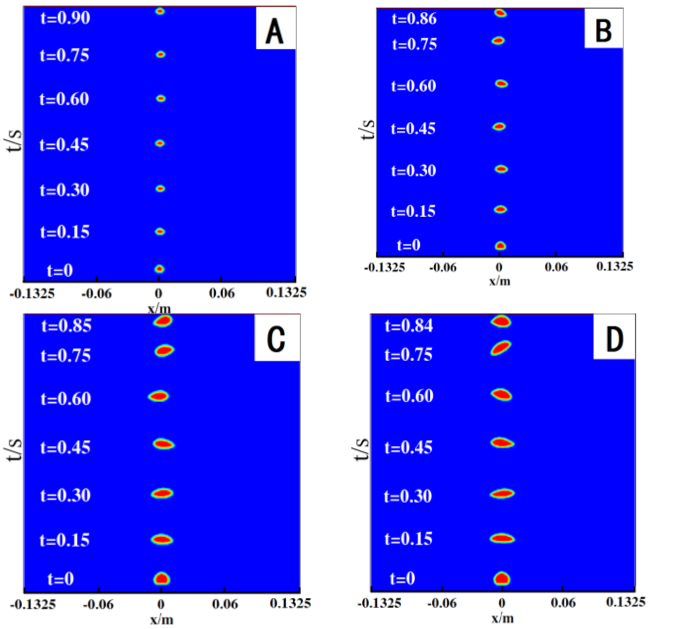

Figure 2: Bubbles rise in the water: (A) D=3mm;(B) D=4mm;(C) D=5mm;(D) D=6mm

Table 2: Rising time and average speed in the water

Diameter/mm	3	4	5	6
Rising time/s	0.9	0.86	0.85	0.84
Average velocity/(m/s)	0.283	0.297	0.3	0.304

3.2 Two bubbles rising in the simulated high temperature melts

Critical merge distance exists while double horizontal bubbles rises in the water, bubbles are hard to coalesce beyond the distance of aperture. Repeated experiments are conducted to confirm the relationship between the critical merge distance and the initial distance of two bubbles (Table 3).

Table 3: Parameters of two bubbles in the simulated high temperature melts

Diameter/mm	Aggregate /mm	No aggregate /mm
3	5.0	5.2
4	5.8	6.0
5	6.6	6.8

As shown in Figure 3A, the bubbles contact after 0.045 s when the bubble space is 5.0 mm. The coalesced bubble rises slowly and turns to an oval gradually, then it reaches the surface of melt after 0.884 s. When the bubbles space is 5.2 mm, these two bubbles never contact with each other, they rise gradually and reach the surface of melt after 0.93 s (Figure 3B). It indicates that the critical merge distance of bubbles is between 5.0 mm and 5.2 mm when the diameter of gas bubbles is 3 mm.

When the space of two bubbles is 5.8 mm, they contact after 0.015 s, coalesced bubble rises gradually until it reaches the surface of melts after 0.85 s (Figure 3C), when the bubbles spacing is 6.0 mm, these two bubbles rise alone without touch until they reach the surface of melts after 0.92 s (Figure 3D). Thus, the critical merge distance is between 5.8 mm and 6.0 mm when the diameter is 4 mm.

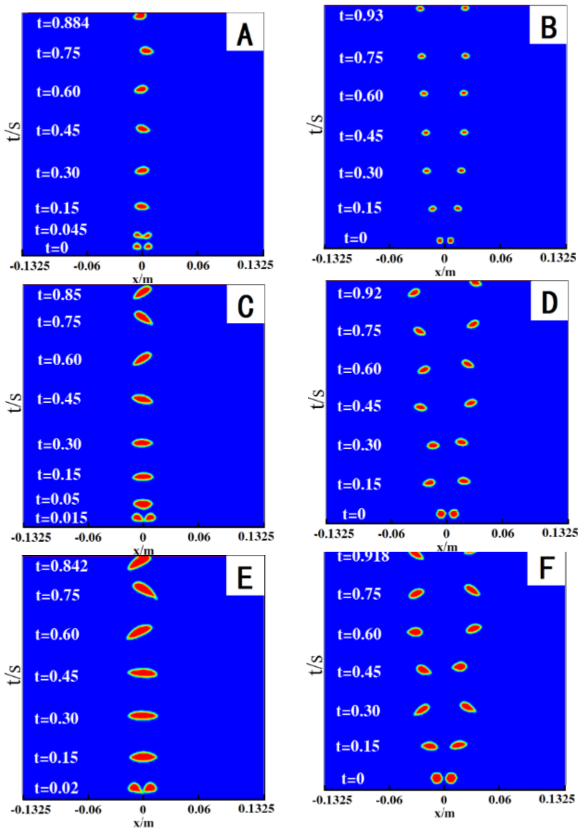

Figure 3: Double bubbles rising behaviors (A) D=3mm, s=5.0mm;(B) D=3mm, s=5.2mm;(C) D=4mm, s=5.8mm;(D) D=4mm, s=6.0mm;(E) D=5mm, s=6.6mm;(F) D=5mm, s=6.8mm

When the bubbles spacing is 6.6 mm, the two bubbles contact and merge after 0.02 s. The coalesced bubble rises gradually until it reaches the surface of melts after 0.842 s (Figure 3E). When the bubbles space is 6.8 mm, these two bubbles never contact until they reach the surface after 0.918 s (Figure 3F). Thus, the critical fusion distance is between 6.6 mm and 6.8 mm when the diameter of gas bubbles is 5 mm.

The simulation results are shown in Table 4. It indicates that the bigger the diameter of the bubbles, the greater of the critical fusion distance. In the process, the shape of the coalesced bubble is concave first and finally becomes a tabular ellipse, and it rolls up constantly.

Table 4. Critical merging distance of different bubbles

Diameter/mm	3	4	5
Critical distance/mm	5.0~5.2	5.8~6.0	6.6~6.8

3.3 Three bubbles rising in the simulated high temperature melts

As shown in Figure 4, when the diameters of bubbles are 3 mm, different bubble spaces have different phenomena [6]. While the bubble space is 5.2 mm, these three bubbles get together and become a large one (Figure 4A), when the bubble space is 5.3 mm and 5.4 mm, these three bubbles never contact, and rise to the surface of melts respectively (Figure 4B, Figure 4C). When the diameters of bubbles are 4 mm, and the space is 6.0 mm, these three bubbles get together to be a large one (Figure 4D), when the space is 6.2 mm, these two bubbles on the left get together, but never contact with the bubble on the right (Figure 4E), when the space is 6.4 mm, these three bubbles rise without contact respectively (Figure 4F).

From these results above, while two bubbles and three bubbles rising in the water under different conditions, both coalescence and separation of gas bubbles exist. In the EAF steelmaking process, As the ejection of slag and metal by CO gas bubbles that burst during decarburization period is the major source of EAF dust, the CO gas bubbles generated from the decarburization reaction, which typically include nucleation at furnace walls, inclusions or slag droplets and growth inside the melts. The CO-bubble size is between 2 and 20 mm [1]. Guézennec suggested that it would be better to reduce dust formation to control the decarburization reaction in order to decrease the CO-bubble size between 1 and 4 mm.

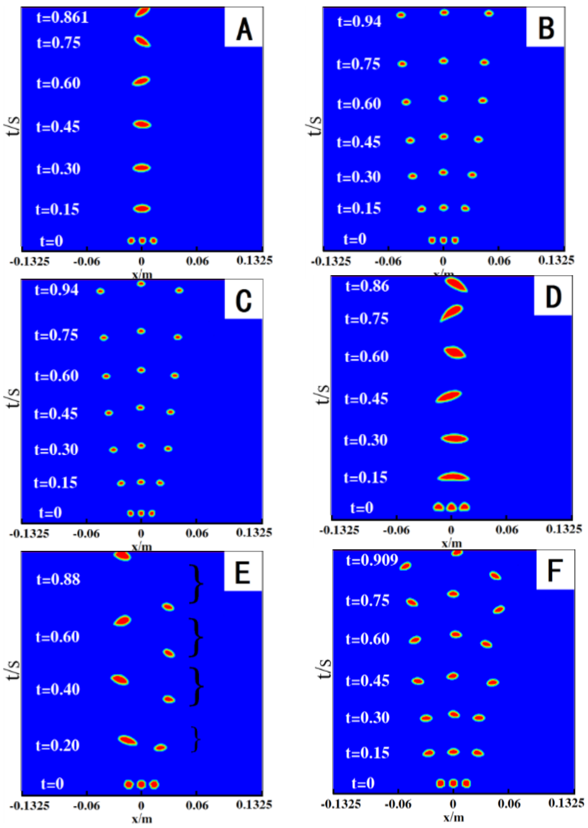

Figure 4: Three bubbles rising behavior: (A) D=3mm, s=5.2mm;(B) D=3mm, s=5.3mm;(C) D=3mm, s=5.4mm;(D) D=4mm, s=6.0mm;(E) D=4mm, s=6.2mm;(F) D=4mm, s=6.4mm

5. CONCLUSIONS

When the initial diameter of the bubble is bigger in the process of bubble rising, the change of the bubble shape is more obvious. When the initial diameter is 3 mm, it presents a circular. While the initial diameter is 5 mm, it likes a cap. Also, the average velocity increases with the increase of the bubble size, so the bigger the bubble size, the more the dust making. Critical merge distance exists while double horizontal bubbles rise in the water, bubbles are hard to coalesce beyond the critical merge distance. When the initial diameter of the bubble is bigger, the critical merge distance is greater. While two bubbles and three bubbles rise in the simulated high temperature melts, both coalescence and separation of gas bubbles exist.

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