

Preface

Refining of metals such as aluminum, copper, iron, and titanium is of essential importance for producing high-quality products in materials engineering at high temperatures. Each metal is initially melted in a reactor and then agitated mainly by gas injection through the gas-lift effect to remove impurities (C, S, P, Mn, and so on) and nonmetallic inclusions (Al_2O_3 , SiO_2 , and so on) contained in it. Fine solid particles (e.g., CaO and CaCO_3) are used as the refining agents and introduced into the reactor from, for example, a top lance. The molten metal flow thus induced in the reactor and the behaviors of the dispersed agents are strongly responsible for the refining efficiency of the process. After refining, the molten metal is usually sent to the continuous casting process which consists of a tundish, an immersion nozzle, and a mold. Finally, the metal is solidified in the mold. Control of the molten metal flow in the casting process is also one of the key technologies producing high-quality products.

The molten metal flows encountered in the above-mentioned materials processes can be characterized as follows:

1. The temperature of the molten metal flows is commonly higher than about $1000\text{ }^\circ\text{C}$ (1273 K). For instance, the temperature of molten steel is around $1600\text{ }^\circ\text{C}$ (1873 K).
2. Every molten metal is opaque.
3. The molten metal flows are highly turbulent and in most cases unsteady and three dimensional.
4. The molten metal flows agitated by gas injection and simultaneously accompanied by powder injection are classified into gas–liquid–solid three-phase flow.
5. Heat transfer and mass transfer take place in addition to metallurgical reactions.

Unfortunately, reliable sensors capable of measuring the velocity of molten metal flows of their temperatures higher than the Curie point of about $700\text{ }^\circ\text{C}$ and of detecting the behavior of bubbles dispersed in the molten metal flow are not available at the present stage. The bubble behavior is characterized by the gas holdup, bubble frequency, rising velocity, and diameter. In addition, detection of solid particles dispersed in the molten metal flow is not easy. According to these

reasons, investigation of molten metal flows in the real processes is very difficult. Cold model investigations therefore have commonly been carried out. Water, mercury, and Wood's metal are chosen as the model working fluid for molten metals. In the steelmaking industry, water is usually used because its kinematic viscosity is very close to that of molten iron. Of course, transparency of water is very convenient for visual observation and the use of water is superior in cost performance. Model studies using water as the working fluid are therefore often carried out also in the copper and aluminum industries.

The flow visualization techniques currently available are very effective in cold model studies for an understanding of the characteristics of the real molten metal flows. This book is devoted to introduce practical visualization techniques and selected applications in materials engineering.

Chapter 1 provides information on materials processes at high temperatures. Particular attention is paid to refining processes agitated by gas injection.

Chapter 2 is devoted to explain the fundamentals of experimental visualization mainly used in cold model experiments.

Chapter 3 presents visualized results of multiphase flows induced by bubble dispersion in cold model experiments.

In Chap. 4, jet-induced rotary sloshing in a cylindrical container is described because a similar phenomenon takes place in a cylindrical bath agitated by gas injection.

Chapter 5 treats the behavior of a rising bubble through an oil/water interface because formation of fine droplets and bubbles associated with the rupture of the bubble is responsible for the refining efficiency.

Chapter 6 discusses continuous casting of molten steel. In particular, possible mechanisms of mold powder entrapment causing steel defects are explained.

Chapter 7 is concerned with wettability problems in materials processing. The inner wall of reactors and pipe elements in materials engineering is usually poorly wetted by molten metals. Fluid flow phenomena close to a poorly wetted wall are different from those close to a wetted wall.

In Chap. 8, miscellaneous applications are introduced.

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