MODELING OF POLYDISPERSED BUBBLY FLOW IN CONTINUOUS CASTING MOLD USING MULTIPLE-SIZE-GROUP MODEL

Zhongqiu Liu[a], Baokuan Li[b], Maofa Jiang[c]
School of Materials and Metallurgy, Northeastern University, Shenyang, China
[a]liuzhongqiu1860@163.com, [b]libk@smm.neu.edu.cn, [c]jiangmf@smm.neu.edu.cn

Abstract. A population balance model based on the Multiple-Size-Group (MUSIG) approach has been developed to investigate the polydispersed bubbly flow inside a slab continuous casting mold. The Eulerian-Eulerian approach is used to describe the motion of the two-phase flow. Sato and Sekiguchi model is used to account for the bubble induced turbulence. Luo and Svendsen model and Prince and Blanch model are used to describe the bubbles breakup and coalescence behavior respectively. A 1/4rd water model of the slab continuous casting mold were applied to investigate the bubble distribution. Against experimental data, numerical results show good agreement for the gas volume fraction and local bubble Sauter mean diameter. The bubble Sauter mean diameter in the upper recirculation zone decreases with increasing water flow rate and increases with increasing gas flow rate. Close agreements between the predictions and measurements demonstrates the capability of the MUSIG model in modeling bubbly flow inside the continuous casting mold.

Keywords: polydispersed bubbly flow, bubble size distribution, Multiple Size Group model, continuous casting mold

Introduction

Transport of argon bubbles dispersed in a turbulent immiscible flow is a common phenomenon in the continuous casting process. Argon gas disintegrates into small bubbles of varying sizes as it issues out of the submerged entrance nozzle (SEN). However, fine argon bubbles were sometimes observed inside the continuous casting slabs [1], which were trapped by the solidified shell. In the subsequent rolling process, these bubbles can lead to the formation of pinhole defects. So understanding the bubble size distribution inside the mold is essential for designing effective methods to remove fine bubbles.

Several water model experiments have been used to study the bubble size distribution in the SEN [2] or mold [3] after air injected through the SEN. Many numerical simulation studies [4,5] have been carried out to assess argon gas injection on the liquid flow in the mold. However, in most simulations of dispersed gas-liquid flow, the local bubble size distribution is not used, but a constant bubble size is used instead.

This work was undertaken to increase the understanding of the bubble size distribution inside the continuous casting mold. Comparisons of gas volume fraction and bubble size distribution with water model experiment data are provided, showing the applicability and accuracy of the model for studying the polydispersed bubbly flow inside the continuous casting mold.

Model Formation and Experimental Details

The population balance model presented in this paper is based on the two-fluid Eulerian-Eulerian approach. To account for non-uniform bubble size distribution, the MUSIG model employs multiple discrete bubble size groups to represent the population balance of bubbles, as shown in Fig.1. In order to measure the bubble size distribution inside the mold and validate the mathematical model, a 1/4rd scaled water model was established. Five experimental photographs at different times under the same flow conditions were used to obtain the mean bubble diameter, and both sides of SEN were analyzed using ImageJ. Then the effects of water flow rate and gas flow rate on the bubble mean diameter were studied. Details can be seen in previous works [6,7].

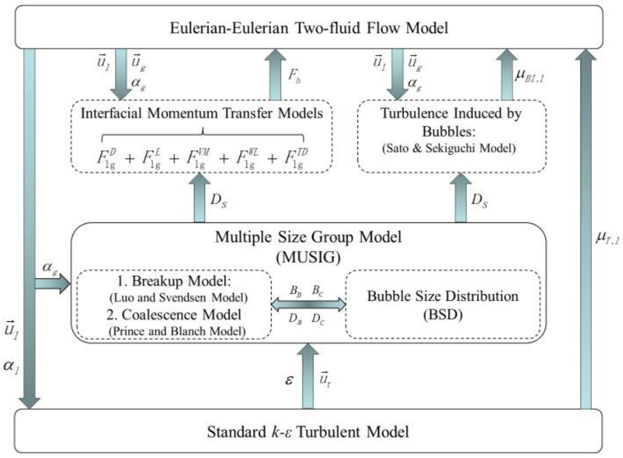

Fig.1. Flow chart of solution methodology

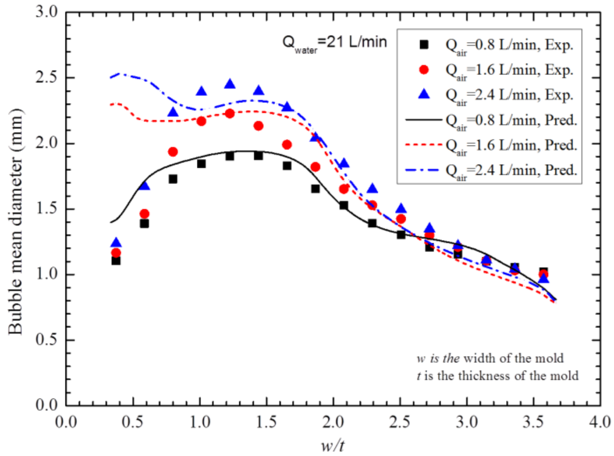

Fig.2. Predicted and measured bubble mean diameter distributions

Conclusions

Eulerian–Eulerian two-fluid model coupled with population balance model for bubbly flow in a slab continuous-casting mold is demonstrated through the implementation of the MUSIG model along with the standard *k-ε* turbulence model for the first time. From the obtained results [6], the following conclusions can be drawn.

(1) At a given gas flow rate, the horizontal bubble dispersion increases with increasing water flow rate. Bubbles tend to float up just in front of the SEN at the lower water flow rate, and at the higher water flow rate bubbles penetrate deeper into the mold.

(2) At a given water flow rate, as shown in Fig.2, the horizontal bubble dispersion decreases with increasing gas flow rate, but not very obvious. More bubbles tend to escape from the top surface close to the SEN and some of them spread into the lower part of the mold.

(3) The bubble mean diameter in the upper recirculation zone decreases with increasing water flow rate and increases with increasing gas flow rate.

(4) The MUSIG model can be considered as a practicable approach for modeling the population balance bubbly flow inside a slab continuous-casting mold.

1. G. Abbel, W. Damen, G. de Gendt and W.Tiekink: *ISIJ Int.*, vol. 36 (1996), pp.219.
2. H. Bai and B.G. Thomas: *Metall Mater. Trans. B*, vol. 32 (2001), pp. 1143.
3. A. Ramos-Banderas, R.D. Morales, R. Sanchez-Perez, L. Garcia-Demedices and G. Solorio-Diaz: *Int. J. Multiphase Flow*, vol. 31(2005), pp. 643.
4. Y.J. Kwon, J. Zhang and H.G. Lee: *ISIJ Int.*, vol. 46 (2006), pp. 257.
5. Z.Q. Liu, B.K. Li, M.F. Jiang and F. Tsukihashi: *ISIJ Int.*, vol. 53(2013), pp. 484.
6. Z.Q. Liu, L.M. Li, F.S. Qi, B.K. Li, M.F. Jiang and F. Tsukihashi: *Metall Mater. Trans. B*, 2014, Online.
7. Z.Q. Liu, B.K. Li, M.F. Jiang and F. Tsukihashi: *ISIJ Int.*, vol. 54 (2014), pp. 1314.