Rectification Effect of 3D-Printed Filters with Deflectors

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Abstract: A novel 3D-printed filter with integrated deflectors is proposed to enhance the state of metal liquid outflow. The rectification effect of filters with varying structural sizes was investigated through physical simulations. It was found that filters with smaller structural sizes allow the outflowing liquid to interact more readily under disturbance, promoting fluid convergence, but at the cost of reduced flow rates. With 3D printing, deflectors were integrated into a larger structural-size filter to guide fluid convergence, significantly enhancing the rectification effect and flow stability without reducing the flow rate. The filters proposed in this work allow for the decoupling of rectification and filtration functions, providing greater design flexibility for improving filter strength, filtration efficiency, and other critical performance attributes.

Keywords: ceramic filter; 3D printing, rectification; deflector

1 Introduction

Extreme application fields such as aerospace engines, gas turbines, and nuclear power plants present significant challenges to the performance of castings[1]. Ceramic filters play an important role in investment casting by filtering impurities, improving the flow state of molten metal, and controlling the flow rate, significantly impacting the performance of the final castings[2–4]. However, the rectification effect of ceramic filters has not received sufficient attention, as the structure of traditional foam ceramic filters can't be designed freely. The chaotic state of the outflowing molten metal could increase the contact area between the metal and air, raising the risk of oxidation and air entrapment, which would increase the number of defects in the final casting[5]. In this work, a novel 3D-printed filter with integrated deflectors is proposed to enhance the rectification effect, making the outflowing molten metal stable and uniform.

2 Experimental procedure

The physical simulation device is shown in Figure 1a. The basic structure of the filter is formed by periodically translating and stacking simple grids, as shown in Figures 1b and 1c. Water was used in place of molten metal to analyze the effect of the filter structure on flow, with blue dye added to make the flow contour visible.

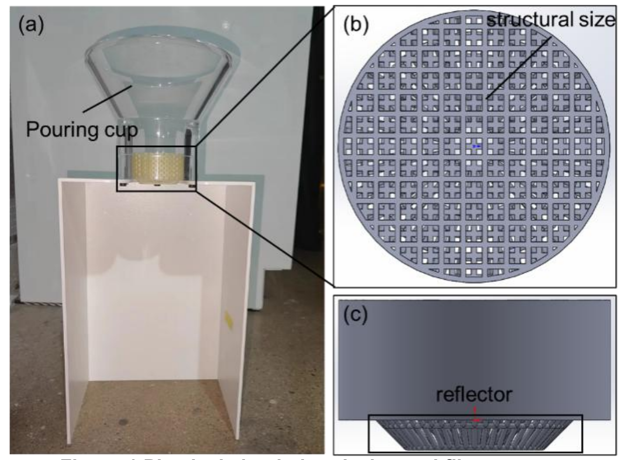

Figure 1 Physical simulation device and filter geometry.

3 Result and discussion

The effect of structural sizes

Filters with 1.5, 1, and 0.5 mm structural sizes were studied As the size decreases, the outflowing metal no longer forms separate liquid columns but shows some degree of convergence, as shown in Figure 2. The improved rectification effect is due to the smaller structural size allowing the outflowing liquid to more easily contact each other under perturbations, leading to convergence under surface tension, as visually recorded in Figure 3. However, because the outflowing liquid is not subjected to the force directing it toward the center, the convergence process primarily relying on perturbations is probabilistic and unstable. Figure 2b shows the convergence in the center, but a significant portion of the separated liquid columns, illustrating the instability of the convergence phenomenon. Additionally, in Figure 2c, the marked reduction in the diameter of the outflowing liquid indicates that fluid flow is significantly obstructed in smaller-sized structures.

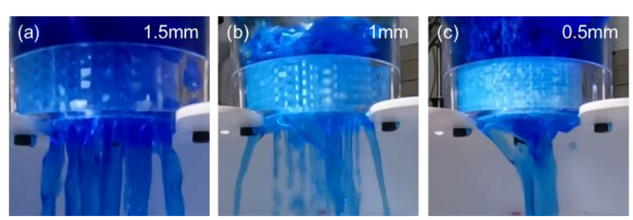

Figure 2 Physical simulations for different structural sizes.

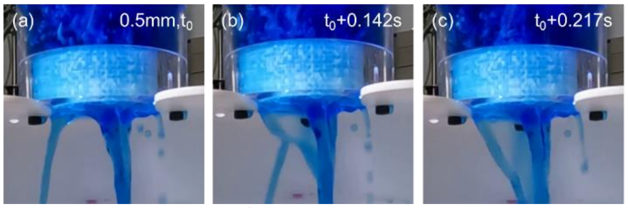

Figure 3 The fluid convergence process.

The effect of deflectors

Various deflectors were integrated into a filter with a 1 mm structural size. As shown in Figure 4, with the increased number and coverage area of the deflectors, the outflow liquid exhibited significant convergence. In Figure 4f, the outflow liquid is uniform, stable, and converged, without impact on the flow rate. Notably, the diameter of the converged outflow corresponds to the external diameter of the deflectors, which indicates that the coverage area of external deflectors determines the affected region. It is attributed to the filter's internal structure, which consists of rod-like elements similar to deflectors, allowing internal deflectors to affect only a limited region of the fluid flow. The deflectors provide the fluid with a centripetal force, enabling stable contact and subsequent convergence under surface tension, as shown in Figure 5. Through 3D printing, deflectors were seamlessly integrated into the filters, achieving a highly effective rectification outcome.

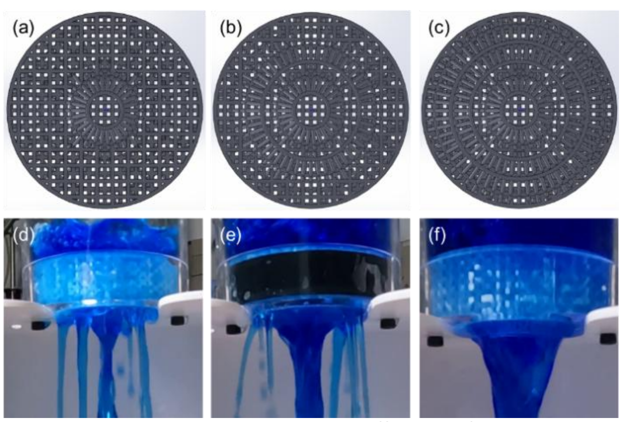

Figure 4 Filters integrated with different deflectors and corresponding physical simulations.

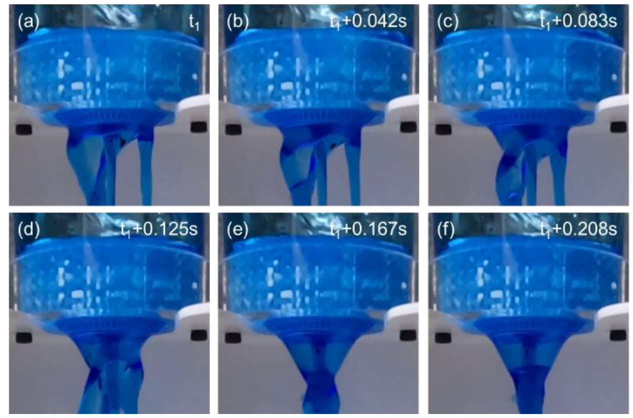

Figure 5 The deflectors guide the fluid convergence.

4 Conclusion

- The rectification effect of the filter was investigated through physical simulations, which was found to be an effective method for further studies.
- Filters with smaller structural sizes exhibit a superior rectification effect but at the cost of reduced flow rates.
- The integration of deflectors significantly improves the rectification effect of the filters and the external coverage area determines the affected region.
- The deflectors through 3D printing decouples the filtration and rectification functions of the filters, enabling designers to prioritize the filters' strength and filtration performance while maintaining rectification.

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