Detection and Segmentation of Cracks and Cold Shut Defects Based on YOLOv8 Algorithm

Zhiqiang Duan[1], Hua Hou[1,3], Yuhong Zhao[1,2,4*]
1. School of Materials Science and Engineering, Collaborative Innovation Center of Ministry of Education and Shanxi Province for High-performance Al/Mg Alloy Materials, North University of China, Taiyuan, 030051, China
2. Beijing Advanced Innovation Center for Materials Genome Engineering, University of Science and Technology Beijing, Beijing, 100083, China
3. School of Materials Science and Engineering, Taiyuan University of Science and Technology, Taiyuan, 030024, China
4. Institute of Materials Intelligent Technology, Liaoning Academy of Materials, Shenyang, 110004, China
*Corresponding address: e-mail: zhaoyuhong@nuc.edu.cn

Abstract: The detection of casting defects is crucial to ensure the quality and performance of the final product. This paper aims to comprehensively explore the advantages and disadvantages of various detection technologies and methods in the field of casting defect detection. On the premise of improving the image quality of aluminum and magnesium alloy casting defects through data enhancement algorithms, a casting defect detection method based on the YOLOv8 instance segmentation algorithm is proposed. The method can effectively detect and segment crack and cold shut defects in castings, and is experimentally verified to have a segmentation confidence level of up to 0.9 and 0.8 for detecting cracks and cold shut defects, respectively. This proves that the method provides an adoptable machine-learning solution for defect detection in castings.

Keywords: Casting Defects, Defect Detection, Data Enhancement, Instance Segmentation, YOLOv8 Algorithm.

1 Introduction

As a traditional metal processing technology, casting is widely used in automobile manufacturing, aerospace, energy and many other fields. The quality of casting products is directly related to the stability and cost-effectiveness of the entire manufacturing process. However, despite the continuous development and improvement of the casting process, casting products are still inevitably plagued by various defects, which may be derived from raw materials, process parameters, operator skills and other factors. These defects not only pose a threat to the quality and performance of the product, but also may cause damage to the equipment, affect production efficiency, and even endanger the safety of personnel.

In this context, casting defect detection has become a key link to ensure product quality and improve production efficiency. The timely detection and solution of casting defects can not only reduce the scrap rate, improve the reliability and durability of products, but also reduce the production cost and improve the competitiveness of enterprises. Therefore, the in-depth research and continuous innovation of casting defect detection technology are of great significance for promoting the development of manufacturing industry and realizing intelligent, green and efficient production.

2 Experimental procedure

Instance Segmentation is one of the most difficult tasks in the four classic visual tasks. It not only has the characteristics of Semantic Segmentation, but also needs to be classified at the pixel level. It also has some characteristics of Object Detection, and it needs to locate different instances, even if they are the same kind. The real challenge of instance segmentation is that it needs to correctly detect the target in the image, determining the contour of the target, and accurately segment each instance at the pixel level.

As a powerful and flexible object detection and image segmentation tool, YOLOv8 introduces new features based on YOLOv5 model to further improve the efficiency and accuracy of the model. One of its key features is scalability, designed as an architecture that supports all previous versions of YOLO, enabling users to easily switch and compare their performance [1]. In addition to scalability, YOLOv8 also introduces a number of innovations, including a new backbone network, anchor-free detection head, and loss function, making it the preferred model for object detection and image segmentation tasks.

3 Result and discussion

Through the statistics of 240 defect data images marked in the data set, the results shown in Fig.1 are obtained. Fig.1(a) represents the size and distribution of the bounding box marked on the defect site, the relative distribution of the defect size in the data set and the center-aligned bounding box are shown in Fig.1(b). The relative width and relative height represent the ratio of the width and height of the target to the width and height of the whole image, respectively. The deeper the color, the more the number of targets corresponding to the size. From Fig.1, it can be observed that the relative size of the target area is mostly concentrated in the range of 0 ~ 0.40, and the small and medium target defects and their boundary frames account for the vast majority.

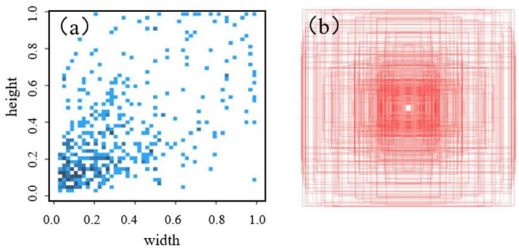

Fig.1 Relative size distribution map of target site.

Subsequently, the YOLOv8 algorithm model was used for training after the enhancement preprocessing of the casting surface defect image. After 200 epochs, the model training set and the verification set reached the lowest and stabilized with the increase of the number of iterations. As shown in Fig.2, the model achieves the best detection state.

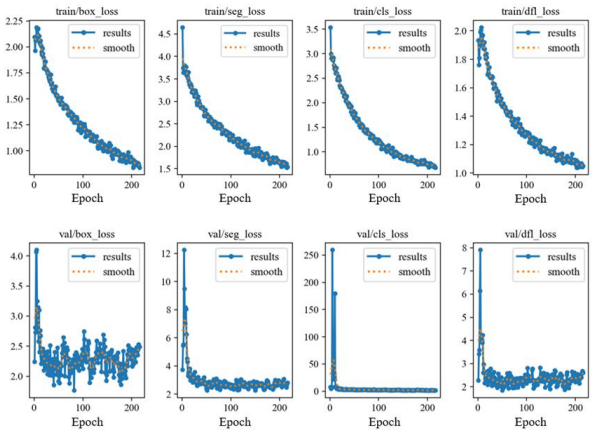

Fig.2 YOLOv8 model dataset is trained on various loss results.

In order to evaluate the detection accuracy of the model, we select the accuracy rate, recall rate, average detection accuracy value (IOU threshold is 0.5) and average detection accuracy value (IOU threshold is in the range of 0.5-0.95) as performance indicators. According to the confusion matrix, the performance index fitting is obtained as shown in Fig. 3. With the increase of the number of iterations, the average precision rate is 0.7375, the average recall rate is 0.581, and the average detection accuracy is close to 0.6.

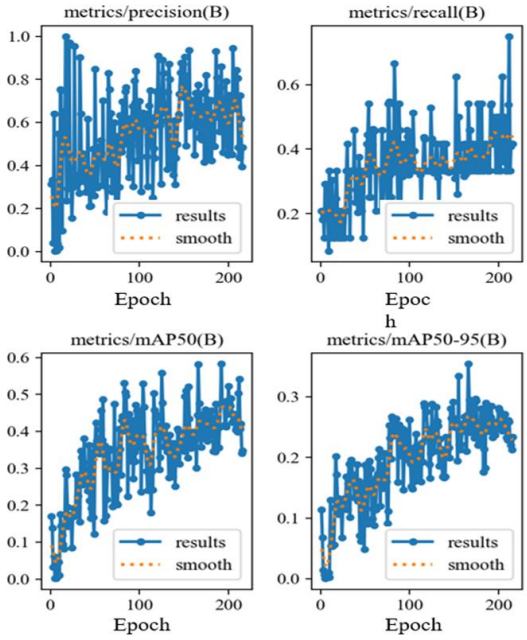

Fig.3 YOLOv8 model performance index training curve.

4 Conclusion

In summary, under the premise of improving the defect image quality of aluminum-magnesium alloy castings by data enhancement algorithm, this paper proposes a casting defect detection method based on YOLOv8 instance segmentation algorithm, which can effectively detect and segment the cracks and cold shut defects of castings. The experimental results show that the segmentation algorithm model based on this example can accurately detect and segment the cold shut and crack defects in the casting defects, and determine the confidence range of the best detection segmentation effect between 0.6-0.8. After subsequent comparison, it is found that the contrast of the defect image after image enhancement and grayscale processing is more obvious, and the defect contour is clearer, which greatly improves the efficiency of the instance segmentation and avoids the phenomenon of missed detection or false detection.

5 Acknowledgments

This work was supported by the National Natural Science Foundation of China (Nos. 52275390, 52375394), Key Research and Development Program of Shanxi Province (202102050201011, 2022ZDYF035)

References

[1] Zhou F, Chao Y, Wang C, Zhang X, Li H, Song X, A small sample nonstandard gear surface defect detection method. Measurement 2023,221:113472.