Research on the High-Temperature Concession of Internal Topology Structure Sand Mold

Baozhi Li[1, 2], Junhang Xu[1, 2], Zhaowei Song[1, 2], Yunbao Gao[1, 2], Jingming Li[1, 2], Zengrui Wang[1, 2,*]
1. National Key Laboratory of Advanced Casting Technologies, Shenyang 110022, China
2. Shenyang Research Institute of Foundry Co., Ltd. CAM, Shenyang 110022, China
*Corresponding address: e-mail: wangzr_srif@foxmail.com

Abstract: For the existing 3DP sand casting, castings are prone to casting crack defects, which increases their scrap rate and greatly wastes resources. Moreover, if castings have crack defects, there will be significant safety hazards after service. One of the reasons for the occurrence of crack defects is the poor high-temperature concession performance of sand molds. Therefore, this article designs various internal topology structures of 3DP sand molds and studies the influence of different internal topology structures on the high-temperature concession performance of sand molds.

Keywords: 3D printed non-mold sand forming; topological structure; high-temperature concession

1 Introduction

3D printing technology allows for flexible and unrestricted design, enabling the production of more complex structures with high dimensional accuracy [1]. Taking advantage of the strengths of 3D printing, numerous scholars have conducted extensive research on the topology structure to further enhance the performance of 3D printed sand molds. Wang et al. [3] proposed a constrained topology optimization method to redesign 3DP sand molds, developing a new design framework for complex structural metal castings. Structural analysis simulations proved that despite a 50% reduction in the bracket weight, the mechanical performance of the optimized design was increased by 30%. Sama et al. [4] found that both parabolic and conical helix sprues improved the quality of complex gating systems when using 3D sand printing. Therefore, the research and practical application of the internal topology structure of 3D printed sand molds are of great significance. Previous studies on the use of sand mold topology focused on complex gating systems, improving the ability to fill shrinkage during solidification, and testing the topology of castings. However, there remains a gap in research regarding the improvement of concession properties and the elimination of crack defects in 3D printed sand molds through modifications in internal topology structure.

2 Experimental procedure

Six samples were prepared using a VX2000 3D experimental machine. The high-temperature thermal expansion stress experiment of the sand molds was conducted using a ZGY resin sand high-temperature performance tester, under controlled conditions of room temperature at (25±5) ℃ and relative humidity at (60±5)%. In this experiment, the samples were placed into a furnace of the ZGY tester preheated to 1,000 ℃ with a preload compression value of 10 N. While maintaining the sample length unchanged, the force values for different samples were recorded, and the maximum value was considered as the limited thermal expansion stress. By comparing the peak values of thermal expansion force among the different samples, an analysis of the improvement in high-temperature concession can be conducted.

Table 1: Internal structure and size of specimen

Sample serial number	Internal mesh shape and size
A	Solid sand mold structure
B	Each layer has 3 mm×2 4 mm square grids, a total of 2 layers, and the square spacing of 2 mm
C	Each layer has 3 mm×2 5 mm square grids, a total of 2 layers, and the square spacing of 2 mm
D	Each layer of 3 mm×2 6 mm cube grid, a total of 2 layers, cube interval of 2 mm
E	Each layer of 3 mm×2 6 mm sphere grid, a total of 2 layers, the sphere spacing of 2 mm
F	The internal cavities are connected to each other. The side length of the bottom surface of the skeleton is 4 mm square , and the interval between parallel cuboids is 2 mm

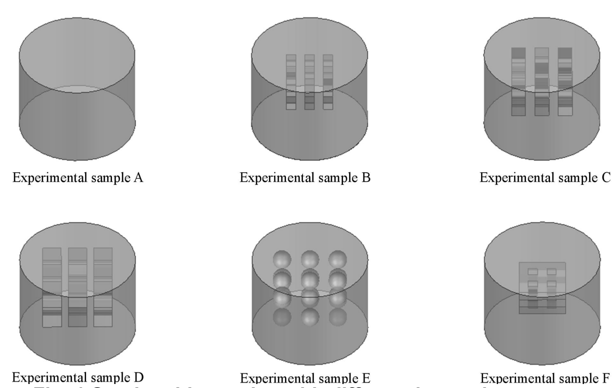

Fig. 1 Sand mold samples with different internal structures

3 Result and discussion

The high-temperature thermal expansion force peak values of different topology grids and skeleton structures are compared, as shown in Fig. 2. The results demonstrate that, in comparison to the original sand mold sample with a peak value of 44.6 N for high-temperature thermal expansion stress, the stress peaks of the modified sand molds with altered internal cavity structures exhibit a reduction of approximately 24.4%-51.3%. Among the various samples, the improvement in thermal expansion stress for the internal structure samples with cubic shapes and side lengths of 4-6 mm is quite similar. It can be seen that as the grid volume increases and the resin content decreases, the thermal stress decreases accordingly. Moreover, the spherical shape with a diameter of 6 mm shows superior retraction performance compared to the internally tangent square with a side length of 4 mm, resulting in a decrease of 4.7 N in thermal expansion stress. The skeleton structure depicted in the figure, which demonstrates the highest reduction of 51.3% in the peak value of high-temperature thermal expansion stress, features interconnected internal topology cavities. This structure ensures sand mold excellent high-temperature concession performance while meeting the required strength for sand backing in casting.

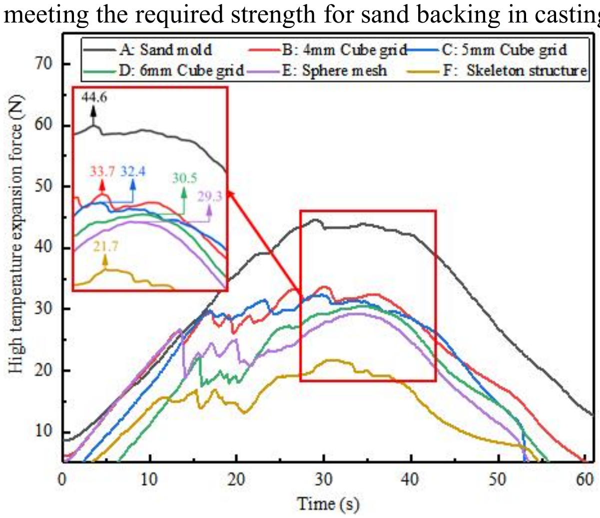

Fig. 2 High-temperature thermal expansion stress curve

4 Conclusion

Due to the improvement of the internal cavity structure, the overall amount of resin added decreased, resulting in a decrease of approximately 24.4%-51.3% in the peak thermal expansion stress compared to the original sand mold sample. The improvement of high-temperature yielding performance of the skeleton structure is excellent. Due to the interconnection of internal topological cavities, the total volume of cavities is larger and can meet the requirements of casting for sand strength. The peak high-temperature thermal expansion stress is reduced by 22.9 N.

References

[1] Shi Y, Zhang J, Wen S, et al. Additive manufacturing and foundry innovation. China Foundry, 2021, 18(4): 286-295.

[2] Wang J, Sama R S, Manogharan G. Re-thinking design methodology for castings: 3D sand-printing and topology optimization. International Journal of Metalcasting, 2019, 13(1): 2-17.

[3] Sama R S, Badamo T, Lynch P, et al. Novel sprue design in metal casting via 3D sand-printing. Additive Manufacturing, 2018, 25: 563–578.

[4] Shangguan H, Kang J, Yi J, et al. The design of the 3D printed lattice reinforced thickness-varying shell mold for casting. Materials, 2018, 11(4): 535-545.