On 3D Printing Spatial Grid Sand Mold

Zhaowei Song, Jingming Li, Rui Chen*, Ling Zhao, Yunbao Gao, Haijun Zhang
National Key Laboratory of Advanced Casting Technologies, China Academy of Machinery Shenyang Research Institute of Foundry Co., Ltd, Shenyang 110022 , P. R. China
*Corresponding address: No.17 Yunfeng South Street, Tiexi District, Shenyang City, Liaoning Province, China.
E-mail: 13998261547@126.com

Abstract: Conventional 3D printing methods face limitations in simultaneously producing a high-strength sand facing layer and a low-strength sand backing layer. The high-strength sand layer typically exhibits poor air permeability and collapsibility, resulting in inefficient use of strength in the central part of the sand mold. In order to address this challenge in 3D printing solid sand molds for casting, a novel approach involving the use of a spatial grid sand mold has been proposed. This method allows for simultaneous printing of high-strength and low-strength sand layers. By employing a spatial grid structure, this approach offers several advantages. It not only optimize the distribution of strength throughout the mold, but also enables the production of sand molds with improved air permeability and collapsibility.

Keywords: spatial meshing, 3D printing, sand mold performance, air permeability

1 Introduction

The origins of 3D printing technology can be traced back to the United States in the 1980s. Over the course of several decades, it has found widespread application in various industries such as automotive, energy, healthcare, and aerospace [1]. Within the realm of casting, the application of 3D printing technology primarily encompasses prototype or pattern printing [2], part printing, as well as sand mold and core printing. There are many advantages associated with 3D printed sand molds. They create a favorable production environment, leverage digital transmission to expedite information exchange, eliminate the need for pattern production, thereby reducing production cycle times, enhancing the dimensional accuracy of sand molds, consequently decreasing the machining allowance for castings, and ensuring product design flexibility.

2 Experimental procedure

As depicted in Fig. 1, when modeling the 3D sand mold for casting, a spatial grid structure is utilized, incorporating a "facing sand layer" whose thickness is contingent upon the sand mold size and the casting specifications. The grid comprises loose sand and is not treated with a binder. Normal printing and spraying operations are conducted within the interstices of the grids. These loose sand grids remain unbonded, with the frames between them constituting the backing sand. Ultimately, the "facing sand" satisfies the casting's strength prerequisites, while the backing sand layer enhances the air permeability of the sand mold, reduces binder consumption, and diminishes gas evolution from the sand mold, thereby lowering costs and enhancing overall mold performance.

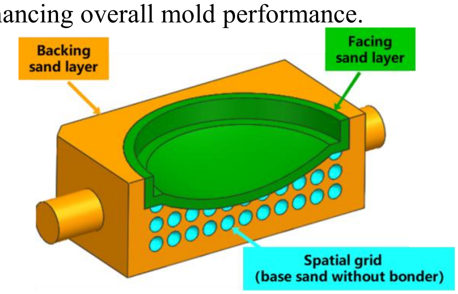


Figure 1 Schematic diagram of cross-section of the spatial meshed sand mold.

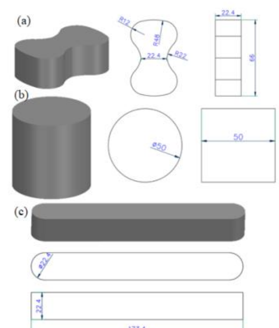
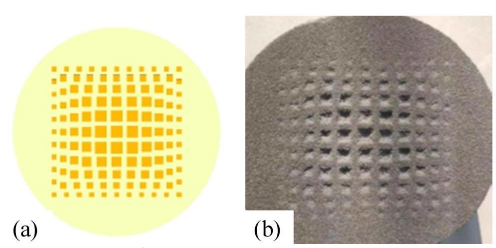


Figure 2 Standard solid sand sample

3 Result and discussion

High surface strength of the mold and good air permeability of the core are desirable during the casting process. In this experiment, cubic grids with a decreasing circumferential sphere diameter from 4 mm to 0.2 mm per layer is employed, arranged concentrically from large to small diameters, thus segmenting the internal space of the sand mold into gradient grids of varying sizes, as shown in Fig. 3. The performances of the gradient mesh sand mold are detailed in Table 1.



(a) (b)

Figure 3 Gradient mesh division diagram.

Table 1 Sand mold performance corresponding to gradient mesh.

Grid shape	Bending strength (MPa)	Tensile strength (MPa)	Compression strength (MPa)	Breathability	Binder dosage ratio	Binder reduction (%)
0-4 mm gradient mesh	1.395	1.178	5.121	160	0.75	42.2
Cube with side length 2 mm	1.395	1.234	4.832	150	0.96	29.6

A space is configured within the interconnected cavity structure, as illustrated in Fig. 4. The cavity takes on a rectangular shape with a bottom side length of 3 mm. The interspace between the rectangular cavity is filled with parallel sprayed adhesive powder sand. This process will be directly executed within the 3D printing sand mold. The detection outcomes are outlined in Table 2.

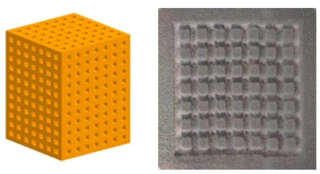


Figure 4 Topological skeleton division diagram.

Table 2 Sand mold performance corresponding to topological frameworkThe simulation employs electrical parameters and input power.

Grid shape	Bending strength (MPa)	Tensile strength (MPa)	Compression strength (MPa)	Breathability	Binder dosage ratio	Binder reduction (%)
Topological skeleton	1.101	0.926	4.114	160	0.65	50%
Cube with side length 3 mm	1.589	1.402	5.402	110	1.14	12.50 %

Combined Table 1 with Table 2, it can be found that the binder dosage is approximately 50% lower than that of the solid sample. The tensile strength, bending strength, and the compressive strength measured 0.925 MPa, 1.101 MPa, and 4.114 MPa, decreased by 42.8%, 0.396%, and 29.1%, respectively, compared to the solid sample, while the air permeability yielded a value of 160, a 190% increase compared to the solid sample.

In comparison to the sand mold comprising 3 mm cubes, the topological skeleton demonstrates an obvously enhancement in air permeability with far less binder dosage. Although the tensile strength is decreased by about 30%, it still meets the casting requirements for the base sand.

The internal penetration of the topological grid's cavity can function as an exhaust channel, leading to a more substantial improvement in air permeability compared to that achieved with a conventional grid.

Furthermore, topology optimization can be employed to further refine the design of the topological skeleton. This involves determining the topological configuration of the connections of the structural elements, as well as the presence or absence of cavities in the structure, along with their number and location, based on the given design domain, constraints, and loading conditions.

4 Conclusion

This study demonstrates that the utilization of spatial grid sand molds can decrease the strength of the sand mold by 10% to 50%, augment air permeability by over 100%, and reduce the amount of binder needed by 10% to 50%. Additionally, the employment of space lattice sand molds improves the deformability, air permeability, and air release of the sand mold. Due to its advantages of low strength, high air permeability, and reduced binder dosage, space lattice sand molds are well-suited for back-sand printing.The strength of a simple cubic packing sand mold is optimal. Hexagonal dense packing and face-centered cubic packing exhibit improved air permeability with reduced binder requirements. The distance mechanism sand between topological cavities enhances air permeability owing to the connectivity between cavities.

Acknowledgments

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References

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