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Laser sintering and laser parameters optimization for porous foam microchannel reactor

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ABSTRACT

Porous foam microchannel reactor can effectively improve the reaction efficiency of Methanol reforming hydrogen production. Currently, porous foam microchannel reactors are primarily formed by the solid phase and liquid phase sintering techniques which generally require the metal fiber sheet of semi-finished products sinter at 800-1000℃ temperature conditions for 30–60 minutes. In this paper, a method of laser-sintered porous metal fiber sintering plate is proposed. Compared with the traditional methods, laser sintering technology has the advantages of shorter sintering time and retaining the surface microstructure which is more conducive to the adhesion of the catalyst. The effects of laser power, scanning rate, scanning distance, and scanning path on the sintering effect were also studied and analyzed. The results show that the porosity of copper fiber laser sintering sheets can reach 80% by laser sintering. When the laser sintering parameters for I = 60A, f = 20Hz, h = 6.5ms, v = 15mm/s, under the condition of variable speed sintering can achieve the best mechanical properties.

1. Introduction

Microreactor, a three-dimensional structural unit, is formed by machining microchannels for chemical reaction and heat exchange on a solid substrate by micro-machining technology. Compared to the traditional scale reactors, microreactors can effectively enhance the quality of the heat transfer process, greatly enhance the fluid and channel contact surface area, and improve the reaction rate and the heat transfer rate without increasing the system's volume. Thus, microreactors are getting more and more attention. At the same time, porous metal materials with the advantages of high porosity, high specific surface area and an abundant surface topography, can support more catalysts under the same volume. Thus, combining microreactors and porous metal materials can effectively improve the performance of microreactors. As Zhou et al. (2015a) reported, by adding porous metal materials in the microreactor, the reaction efficiency of microchannel reactor can be effectively improved. In the same year, Zhou et al. (2015b) found that the heat and mass transfer rate were also improved after using porous metal materials. Similar experimental results were obtained by Liang et al. (2017). After combining the Cu-Zn/Al foam monolithic catalyst and the microchannel reactor, heat/mass transfer ability and the reaction efficiency had been greatly improved. So, porous metal materials have been considered as an ideal catalyst carrier for microreactors.

Porous metal fiber sintered plate, one type of porous metal materials, is generally fabricated by turning or extrusion drawing to process the raw material. Next the semi-finished materials manufactured after a specific pre-treatment method and then prepared through sintering technology. In the previous research, Tang et al. (2010) prepared porous metal fiber sintered felt by plate-laminated mold pressing and solid-state sintering method. The results found that the sintering temperature had a great influence on the molding of the fiberboard during the process of the high-temperature solid phase sintering. Zhou et al. (2012) further confirmed that the sintering temperature has a great influence on the sintering quality of the felt by conducting a uniaxial compressive test to the porous metal fiber sintered felt. The results found that when the temperature was too low, it was difficult to make the sintering mold. On the other hand, the temperature was too high leading to the formation of the bulk structure of the fiberboard, which caused the disappearance of the microscopic characterises of the metal fiber. And the disappearance of microscopic features greatly weakens the adhesion ability of the catalyst, thereby affecting the catalytic reaction rate. In addition, the disappearance of micro structural features on the surface of the metal fibers also results in a reduction in the specific surface area resulting in a catalyst loading reduction. Therefore, it is an urgent problem to as much as possible ensure the rich microscopic features of the metal fiber while the metal fiber- board is sintered.

Laser sintering, by using high-intensity laser beam radiation on the metal surface, has the advantages of a wide range of sintering materials,

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fast sintering speed and small heat-affected range. Recently, laser sintering has drawn much attention. Olakanmi et al. (2015) analyzed the progress of aluminum alloy powders in selective laser sintering/melting (SLS/SLM) and designed aluminum alloys suitable for SLS/SLM processes. Kinstlinger et al. (2016) developed a low-cost, open-source selective laser sintering system and demonstrated its capacity to fabricate structures in nylon with sub-millimeter features and overhanging regions. Yuan et al. (2016) proposed a dual experimental-theoretical method to evaluate and optimize CNT-coated polymer powders for selective laser sintering. Singh et al. (2017) studied the effect of different sintering parameters on the hardness and density of laser sintered parts and designed a surface centric centered composite design for laser sintering parameter optimization. Wu et al. (2018) studied the effect of laser parameters on microstructure, metallurgical defects and property of ALSi10Mg printed by selective laser melting. Mohan et al. (2017) summarized the current research of laser sintering technology and look forward to the future direction of laser sintering technology optimization. Shen et al. (2018) develops process efficiency maps for selective laser sintering of polymeric composite powders to provide guidance for process parameter optimization via numerical modeling and experimental testing. Stichel et al. (2018) studied the effect of process parameters on the pore morphology by selective laser sintering of polymers. Although laser sintering has drawn much attention in various fields, no one has yet applied laser sintering to metal fiberboard sintering. In the meantime, due to the rapidity and small heat-affected range, laser sintering can mostly reserve the rich microscopic features of the fiberboard, which makes it the most ideal way to sinter the metal fiber. In this paper, the plate-laminated mold pressing and laser sintering method were used to form the porous metal fiber sintered plate. Additionally, the forming of the laser-sintered metal fiber-board was analyzed and the influence of laser power density, scanning rate, and scanning pitch on the mechanical properties of porous metal fiber sintered plate was studied.

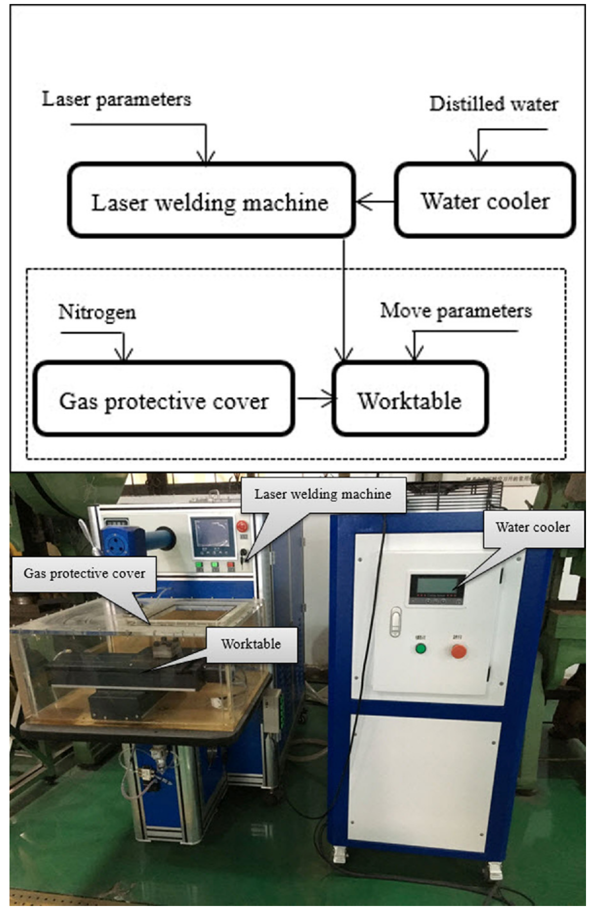

Fig. 2. Fiber-sheet laser-sintering device and its schematic diagram.

2. Experiment

In this paper, the laser-sintering fiber-mold is shown in Fig. 1. It consists of the base, middle cavity, block, press plate, and bolts. The mold is made of sus304 material and its melting point is higher than that of copper to avoid fusion of the mold material with copper fibers during laser-sintering. An opening is left in the press plate so that the laser beam can be transmitted to hold the fiber-sintering area. The rectangular cavity in the middle opening was used for the sintered fibers, which are 30 mm*30 mm*2 mm.

Before sintering, copper fibers were uniformly spread in the middle rectangular cavity in the sintering mold, and then the block was placed and subjected to a certain pressure. Next, the bolt-locking mold was tightened to obtain the shape of the size of 30 mm*30 mm*2 mm. The copper-fiber sintered sheet was semi-finished before performing the laser-sintering and the block was removed. Finally, the formed semi-finished product could be laser-sintered through the opening reserved on the upper platen.

In this experiment, the laser-sintering device was transformed and established an ordinary laser welding machine, which was achieved by using metal fiber sintering plate laser automatic welding. The laser sintering device is mainly composed of a laser-welding machine, a worktable, a water cooler, and protective gas covering four parts as showed in Fig.2. Among them, the laser-welding machine mainly includes laser power control, a pump pulse xenon lamp, and a pump YAG crystal. Below the laser welding table, the X, Y direction of the motion table was added by the servo motor control, and was equipped with

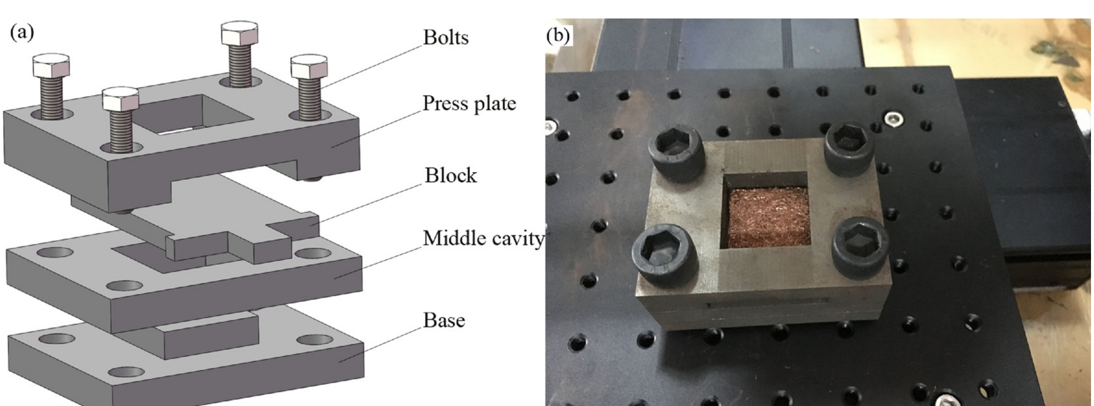

Fig. 1. Mold structure of laser sintered fiber sheet.