Fabrication of Gas-permeable Die Materials Having Orthogonally Arrayed Pore Channels

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Abstract

Gas-permeable metal die materials are developed using tool steel powder, packed in a mold having the insertion of orthogonally arrayed polymer wires. Linear gas-permeable channels in orthogonal array are thus developed by the burning out of the polymer wires, which yield a microstructure with wear resistance value and air permeability much larger than those of the conventional gas-permeable die material.

Keywords : gas-permeable metal die material, powders, sintering, permeability

1. Introduction

Gas-permeable steels are widely used in industries, such as gas-permeable mold insert, vacuum suction plate, and particulate filtration. The process required to make the gas-permeable structures are either loose powder sintering of steel powders or micro-drilling of steels bulks. Both processes have many limitation of applications[1-3]. The goal of this study was to make a porous steel structure by sintering a loosely packed powder structure, within which was buried with sacrificing pre-woven fibers of three-dimensional orthogonal structure [4]. The gas permeability value could be controlled by optimizing the diameter and the woven density of the pre-woven fibers, and the sintering temperature.

2. Experimental and Results

The powder used in this study is a M2 steel powder (Fe-6W-5Mo 4Cr-2V-1C, wt%) with a mean particle size of about 4.4 µm. The gas-permeating channels of the sintered structure were formed by sintering a fiber-embedded loosely packed M2 powder structure, in which sacrificing pre-woven fibers of three-dimensional orthogonal structure were buried in the loosely packed M2 steel powder. First, graphite plates with drilled channels were assembled into a container, where the separation between each channel was either 2 mm or 4 mm. Polymer fibers of 60 µm, 90 µm or120 µm in diameter were subsequently woven along the graphite plates, forming the orthogonal structure. The sintering temperature was set at either 1260 °C,1300 °C or 1340 °C, and held for 30 minutes. The gas permeability value of the sintered structure was measured by employing a Gas Permeability Test using an Automated Capillary Flow Porometer (Porous Materials, Inc.). The hardness of the sintered structure was determined using a Rockwell C scale tester, while the strength was determined by a three-point bending test. The abrasion resistance of the specimen was determined by grinding the steel against a sand paper of 400 in mesh size under a load of 0.28 N/mm^2 in an automatic polishing machine. The weight loss after 5 minutes grinding was determined.

Figure 1 shows the polished surfaces of the commercial product (SUS 430) and the samples sintered at different temperatures. It can be observed that the pore channels are arranged regularly for the specimens investigated in this study, compared with the non-uniform distribution of the commercial product.

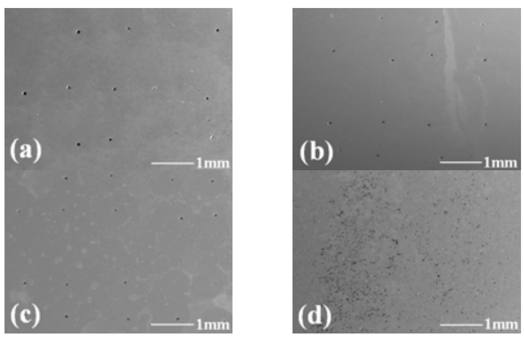

Fig. 1. Polished surfaces for the specimens sintered at (a)1260 °C, (b) 1300 °C, and (c)1340 °C, respectively and (d) that of a commercial product.

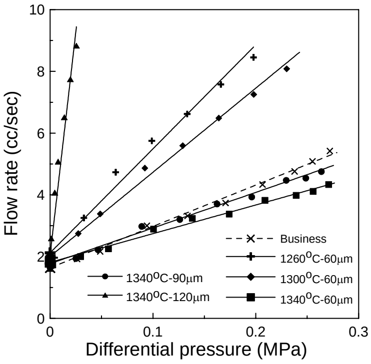

Fig. 2. Gas flow rate versus differential pressure for the specimens processed at various conditions and that of a commercial product.

Figure 2 compares the gas-permeating results for the commercial product and the specimens processed at different conditions. It can be observed that the specimens, using the fibers of 60 μm and 90 μm in diameter, sintered at 1340 °C had permeability values comparable to that of the commercial one, while that, using the fibers of 120 μm, sintered at 1340 °C had the largest value of permeability in this study. On the other hand, the specimens, using the fibers of 60 μm in diameter, sintered at lower temperatures also yielded larger permeability values than that of the commercial one. Table 1 shows a comparison of the properties of the porous steels investigated in this study and those of the commercial one. It can be observed from this comparison that, compared with the commercial product, not only can the gas permeability value be enhanced for the porous steels prepared in this study, but also improvements can be made on the other properties related to structural strength and wear resistance.

3. Reference

1. I. P. Tuersley, A. Jawaid, I. R. Pashby, J. of Mat. Pro. Tech., 42, p.377-390, (1994).
2. D.G. Lee, H.G. Lee, P.J. Kim, K.G. Bang, Inter. J. of Machine Tools & Manufacture, 43, p.551-558, (2003).
3. H. Zheng, E. Gan, G. C. Lim, Optics and Lasers in Eingeering, 36, p.355-371, (2001).
4. T.Y. Chan, S.T. Lin, C.S. Lee, R.O.C, P.R.C and U.S. Patent pending(2005/08).

Table 1. A comparison of the properties investigated in this study and those of the commercial one

Designation		Sintering Temp. (°C)			Commercial Product (SUS430)
Property	Fiber Diameter(μm)	1260 °C	1300 °C	1340 °C	
Average Channel Diameter (μm)	60	73.5	63.6	52.8	7
	90	101.8	92.3	70.3	
	120	133	125.5	110	
Density (g/cm3)	60	7.87	8.03	8.1	6.23
Hardness (HRC)	60	51.6	57.8	60.9	37.5
Porosity (%)	60	4.1	2.1	1.2	22.1
Wear Rate (%)	60	2.07	1.99	1.87	4.37