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Fabrication of sintered steel wire mesh and its compressive properties

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Abstract

Porous steel wire mesh with open porosities of 33.90–56.27% and pore sizes of 25–1300 μm has been prepared by metallurgical route. The porous morphologies and porosities of the wire mesh have been investigated in terms of forming pressure, sintering temperature and sintering holding time. The pore size distribution in the as-prepared samples has been determined by means of metallographic statistic measurement. The results indicate that the total and open porosities are closely related to the forming pressure. Higher sintering temperature and longer holding time in the range of our experiments lead to finer porous structure, coarser joints between wires, and lower porosities. The steel wire mesh exhibits three-stage elastic–plastic behaviors under compressive loading which are similar to that of other cellular materials. The yield strength and Young's modulus of the steel wire mesh decrease rapidly with the increase in porosities. When the porosity increases from 33.90 to 56.27%, the yield strength drops from 46.9 to 14.8 MPa and the Young's modulus drops from 1.42 to 0.42 GPa.

Keywords: Wire mesh; Porous metals; Fiber mesh; Sintering; Porosities

1. Introduction

Porous metals or alloys usually exhibit high capacities of energy absorption (voice absorption and shock absorption), permeability, fire retardant and heat resistance. With those novel physical and mechanical properties they have been widely used in various industrial fields (such as metallurgy, machinery, petrochemicals, construction, medicine, environment, atomic energy, etc.) as intermediate materials for filtration, separation, distributing gas, catalyze, electrochemistry process, noise-damping, shock absorption and heat exchange in aviation and astronavigation [1,2]. Many ways can contribute to fabricating porous metallic materials [1–6]. Besides the two popular industrial methods—metal powder sintering [3,4] and metallurgical cast [5,6] (the former may produce open-cell porous structure with homogeneous/non-homogeneous pore distribution; the latter usually produces closed-cell porous structure with non-homogeneous pore distribution), there are many other methods to fabricate greater porosity or more homogeneous porous structure with specific property and purpose. For example, fiber sintering [3,7–9], space holder method [10] and replication method [11] have been used to produce the porous materials with well-controlled porosities and pore distributions. Among which, fiber sintering or sintered wire mesh has shown advantages to avoid the problems that could happen with the powder metallurgy. For exploring the fabrication technologies of sintered metal mesh, a set of steel wire mesh has been prepared by metallurgic route in this paper. The porous structure, porosity, pore size and distribution, liquid absorption and compressive properties of the as-prepared sintered steel wire mesh are investigated. The effect of the forming pressure and sintering parameters on the porous structure and the compressive properties are discussed.

2. Experimental procedures

2.1. Fabrication of the sintered porous steel wire mesh

The steel wire with diameter of 0.3 mm has been used to fabricate the porous steel wire mesh (the wire in this size is easily twisted and deformed). Its chemical compositions (wt.%) and mechanical properties are listed in Table 1. The fabrication method of the sintered porous steel wire mesh can be described in following steps. At first, the steel wire is preformed by wire

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Table 1
Chemical compositions (wt.%) and mechanical properties of Q195F steel wire

Fe	C	Si	Mn	P	S	Yield point (MPa)	Tensile strength (MPa)	Elongation (%)
Balance	0.06–0.12	≤0.05	0.25–0.50	≤0.040	≤0.040	≥195	≤390	≥30

distortion and twist to form a loose clew-like steel wire bundle. Secondly, the wire bundle is put into a specially designed cylinder-piston device with cave size of 20 mm in diameter. The cylindrical samples of the porous wire mesh are formed in the device by applying a pressure on the piston-rod for a period of time. The pressure is controlled in a range of 31.8 and 79.6 MPa. The holding time under the pressure is more than 10 s. The porosity of the wire mesh can be controlled by changing the pressure on the piston-rod. After formation of the wire mesh, the compacted cylindrical samples are finally sintered in a furnace in vacuum (the chamber pressure is less than 1×10^{-2} Pa). The sintering temperature is controlled at 1373 and 1473 K, and the sintering holding time is 3 and 5 h, respectively. Different sintering temperature and holding time may lead to different porosities and various mechanical properties of the wire mesh.

2.2. Characteristics of the sintered porous steel wire mesh

The pore morphologies of the steel wire mesh were observed by using an optical microscope and a JEOL-JSM 6460 scanning electron microscope (SEM). The pore size and the size distribution were determined by means of mathematical statistics and the commercial Image pro Discovery software under optical microscope. Five viewpoints were chosen from the cross and longitudinal sections of each sample.

According to the Archimedes theory, the total and open porosities can be determined by the hydrostatic weighing method [12]. For this purpose, the samples were dried in an electrothermal constant-temperature blast dry box (UHG-9023A) at 378 K for 2 h, then cooled in a desiccator to room temperature. The mass of the dried samples, m_1, was measured by using an AL104 METTLER TOLEDO balance. Subsequently, the sample was put into a container in which the inner air was evacuated by using a vacuum pump for 5 min. A kind of liquid, which can be absorbed by the prepared porous sample, was poured into the container until to submerge the sample completely. Then the container was pumped again for 30 min. The apparent mass, m_2, of the saturated porous sample (filled with the liquid) was measured in the liquid. Meanwhile, the mass of the saturated porous sample in air, m_3, can be also measured. The data error of the measurement is less than 0.001 g.

According to the measured values, liquid absorption, the mass ratio of the liquid absorbed and the porous wire mesh sample, can be calculated by following equation.

$$W_a = \frac{m_3 - m_1}{m_1} \tag{1}$$

The open porosity, P_a (the open-pores volume divided by the wire mesh sample volume) can be expressed as the following equation.

$$P_a = \frac{m_3 - m_1}{m_3 - m_2} \tag{2}$$

The bulk density, D_b (the mass of the porous wire mesh sample divided by the sample volume) can be derived from a simple substitution.

$$D_b = \frac{m_1 D_l}{m_3 - m_2} \tag{3}$$

where D_l is the density of the steeping liquid at test temperature. Considering the total pores volume (including open-pores and closed-pores) in the sample, the total porosity, P_t (the total pores volume in the sample divided by the sample volume) can be expressed as the following equation.

$$P_t = \frac{D_t - D_b}{D_t} \tag{4}$$

where D_t is the density of the steel wire.

The compressive stress–strain behavior of the porous wire mesh sample was investigated by using a testing machine (AG-100KNA). The specimen size is 20 mm in diameter and 30 mm in length. The strain rate is $1.7 \times 10^{-3}\ \mathrm{s}^{-1}$.

3. Results and discussion

3.1. Typical porous structure of the sintered steel wire mesh

Fig. 1 shows the appearance of the as-prepared steel wire mesh sample with 20 mm in diameter and 55 mm in length. By further observation under microscope the compact wire mesh structure can be clearly shown (Fig. 2). The pores formed among

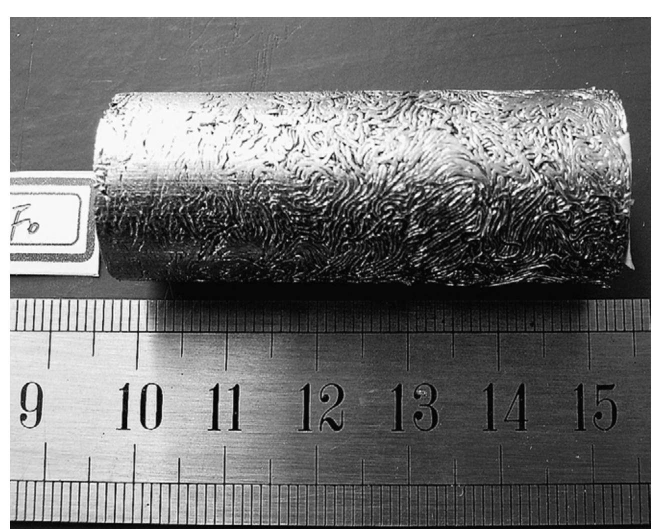

Fig. 1. The as-prepared steel wire mesh sample.