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Experimental study, on strain rate sensitivity of ductile porous irons

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ABSTRACT

Experimental investigation on the behavior of porous irons under compression loading, especially at high strain rate compression loading, is carried out in this study to help understanding the effects of strain rate and porosity on the yield strength, energy absorption and load carrying capacity of this group of porous metals. Samples of porous iron with porosity ranging from 10% to 35% were fabricated by the powder metallurgy technology. The tests were conducted at a wide range of strain rates from 10^{-3} to 10^{3}/s using a servo-hydraulic machine and a split Hopkinson pressure bar (SHPB) system. It has been found from the results that the material shows a bi-linear behavior over the tested strain rates. The porosity has a direct effect on the yield strength and post yield behavior of the material, while the yield strength, load carrying capacity and energy absorption capability of porous irons vary with the strain rate. Findings are being used to develop a phenomenological constitutive model for porous irons.

1. Introduction

Extensive work has been seen on developing materials with multiple functionality such as high strength, high energy absorption and high load carrying capacity with considerable reduction in weight [1,2]. Porous metals, which belong to the category of cellular materials, are attractive because they offer significant reduction in weight alongside good potential in impact energy absorption and load carrying capacity. Metallic foams (with porosity larger than 70%) are generally very good in energy absorption; however, their use in structural components is limited due to the lower strengths. In comparison, porous metals, with porosity in the range of 10%–70%, have the density ranging between those of typical solids and metallic foams and possess weight efficiency alongside appropriate strength, making them suitable for structural applications.

Metallic foams have been widely studied, e.g [1–4]. However, limited studies have been reported on porous metals, particularly for their behavior under high strain rate loading. Using the powder metallurgy method, Wang et al. [5–7] produced porous bronze and porous iron with porosity ranging from 10% to 40%. Quasi-static and low strain rate tests were carried out to characterize their mechanical behavior. The materials are found to be compressible in large deformation and the strain rate effects are prominent. Zhu et al. [8] produced porous TiNi by powder sintering technique under argon gas, and studied the effects of the parameters of powder sintering technique on the elastic modulus, the maximum compression and bending strengths. Porous NiTi produced by gas expansion technique was studied and their kinetic properties like stiffness, strength and super-elastic recovery were reported for human bones implants [9]. Zhang et al. [10] produced porous coppers by space holder technique using polymer powder in sintering and their mechanical properties were investigated under quasi-static compression tests. It was found that their elastic modulus, strain hardening and yield strength vary inversely with porosity. Da Silva et al. [11] studied strain rate dependence of porous iron experimentally and a visco-plastic model for porous pure iron was built. They used porous iron with porosity range between 0% and 31% and conducted quasi-static as well as high strain rate tests using SHPB. Their study revealed that the strain rate sensitivity of porous iron is result of strain rate sensitivity of fully dense iron produced by same process. Recently experimental data for 20–40% porous bronze with quasi-static as well as high strain rate testing was presented [12]. Influence of strain rate and porosity on material properties like yield strength, energy absorption capability and load carrying capacity were discussed.

Porous materials based on heavy metals like iron are important candidates in industry for structural uses. They possess a high melting temperature, high strength, good manufacturability and compatibility with many existing structures [2]. Powder metallurgy is an effective technique to produce porous

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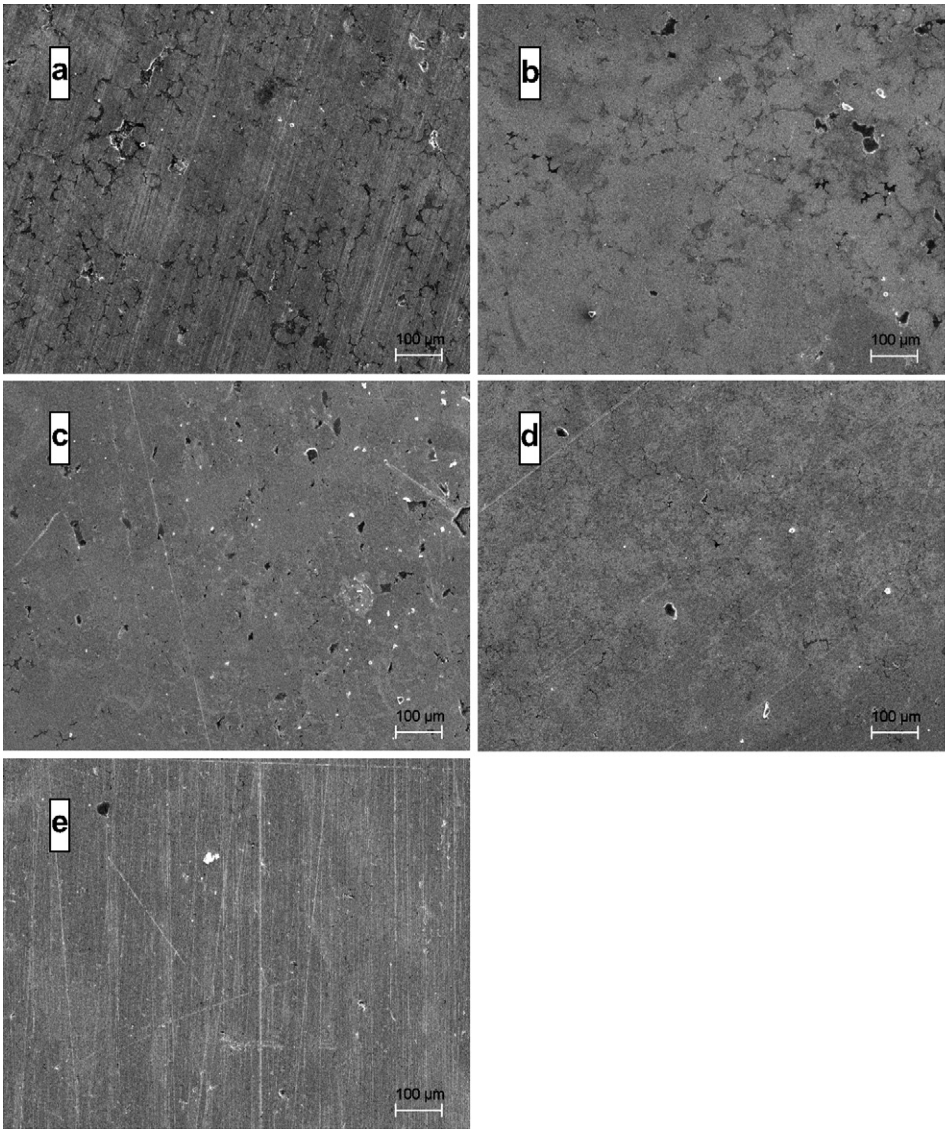

Fig. 1. SEM micrograph (300×) of vertical sectioning of porous iron samples a) 34% porous, b) 30% Porous, c) 21% Porous, d) 17% Porous, e) 13% porous.

materials with various porosities by varying the compaction pressure during the forming process. Present study is aimed to investigate the effects of strain rate and porosity on the material's behavior in terms of yield strength and energy absorption capability. Some empirical relations on the basis of data obtained are given to help selection of suitable porosity of porous iron for given applications.

2. Experimental setup

2.1. Material and sample preparation

Porous irons with porosities 34%, 30%, 21%, 17% and 13% were fabricated using powder metallurgy technique. SEM micrographs of different porosities of porous iron are shown in Fig. 1 to show the morphology of the pores in the produced material.

Due to the porous nature of the material, attention is required in deciding the size of specimen in order to obtain good repeatability in measurement. It was suggested [3] that the size of a specimen should be at least 10–20 times greater than the nominal pore size to obtain the overall average mechanical behavior of the material. Based on SEM assessment of the sample material, cylindrical specimens of diameter 7.5 mm and length 7.5 mm were prepared for 5 different porosities of porous irons.

Table 1
Porosity and corresponding density of the specimens.

	Porous irons				
Density(g/cm^3)	5.28	5.54	6.21	6.54	6.81
Porosity	34%	30%	21%	17%	13%

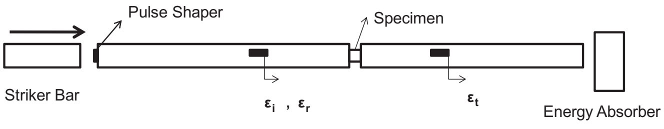

Fig. 2. Schematic drawing of SHPB.