BENDING TESTS OF POROUS STEEL MANUFACTURED BY LOST CARBONATE SINTERING

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Introduction

The unique combination of properties of porous metals has led to a noticeable rapid increase in their applications (Banhart, 2001). One particular area of application is in impact energy absorption and lightweight structures, because of their ability of large amount of plastic deformation and high specific strength and stiffness.

Porous metals, especially those produced by powder metallurgy based methods, have relatively low tensile strength, so they are normally characterised by compression and bending. Three-point bending tests on porous steel manufactured by the lost carbonate sintering (LCS) process have been conducted by Zhang & Zhao (2008) and Lu & Zhao (2010). Although three-point bending is preferable due to the comparative simplicity in the testing procedure, it may produce erroneous results due to stress concentration. In this case, four-point bending, which examines a larger portion of the sample by imposing the same stress without the shear stress effect, may be necessary. This paper compares the mechanical properties of LCS porous steel obtained by three- and four-point bending tests.

Experimental

Porous steel samples were manufactured by LCS via the dissolution route (Zhao et al., 2005). Astaloy A steel powder was mixed with K_2CO_3 (425-750 µm), with the volume percentage of steel being 25– 50%. The mixture was compressed in a cylindrical steel tube by a hydraulic press at 200 MPa. The compacts were heated in a muffle furnace at 240°C for two hours to evaporate the binder and sintered at 855°C for four hours. The compacts were then cooled to room temperature and the K_2CO_3 particles were removed by dissolution in water.

The porous steel samples were cut into compression (10×10×20 mm) and bending (10×10×40 mm) specimens. The compression and bending tests were conducted on an Instron 4505 mechanical tester. The flexural strength was obtained as follows:

For three-point bending (ASTM E855),

$$\sigma = \frac{3\,F\,L}{2\,b\,d^2}$$

and for four-point bending (ASTM D6272),

$$\sigma = \frac{F\,L}{b\,d^2}$$

where σ is flexural strength, F is maximum applied force, L is span length, b is width of specimen and d is depth of specimen.

Results and Discussion

Compressive strength increased nearly linearly with relative density in the tested range, as shown in Fig. 1.

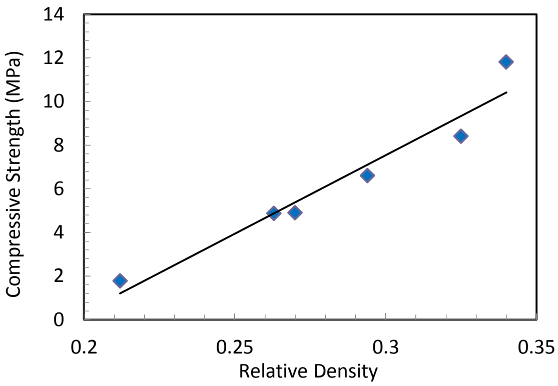

Fig. 1 Compressive strength as a function of relative density

The flexural strength as a function of relative density obtained for both three- and four-point bending is shown in Fig. 2. In the current three- and four-point bending test conditions, the normal stress was much higher than the shear stress.

Therefore, failures were caused by normal stresses. In fact, fractures started at the outer layer due to tensile stress. Fig. 2 shows that the results obtained by the two bending tests were similar. However, the data obtained from four-point bending were less scattered and more consistent than those from three-point bending. The flexural strength at any relative density was comparable to the compressive strength shown in Fig. 1.

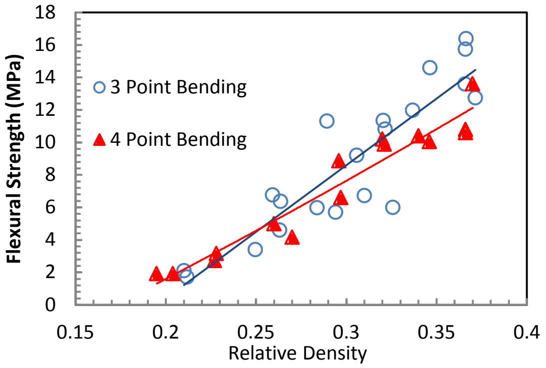

Fig. 2 Flexural strength as a function of relative density

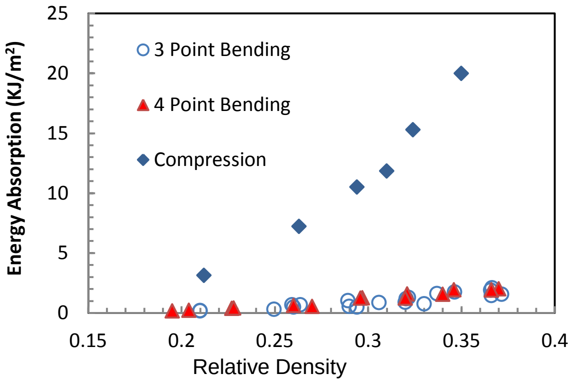

Fig. 3 Energy absorbed as a function of relative density

Fig. 3 shows the energy absorbed by the specimens in compression, and three- and four-point bending, expressed in terms of energy absorption per unit cross-sectional area (Tao et al. 2007). The amount of energy absorbed in compression was much larger than that in three- or four-point bending. This is mainly because plastic deformation spreads over the whole specimen in compression but is concentrated in a smaller region in bending.

The stress conditions in compression and bending are different. The porous steel specimens normally exhibit plastic deformation under compressive stress in compression. They are more likely to fail by brittle fracture in three- and four-point bending due to tensile stress. All of these observations indicate that the porous steel specimens performed better in compression than in bending.

Conclusion

Porous steel samples with pore size of 425-750 μm and porosity ranging from 50% to 75% were manufactured by LCS via the dissolution route. Compression and three- and four-point tests were conducted. Although the flexural strength values obtained from four-point bending were less scattered and more consistent, they were similar to those obtained by three-point bending, indicating that three-point bending tests were acceptable for most cases. The flexural strength at any relative density was comparable to the compressive strength.

References

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