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The effect of binder and plasticizer on porous titanium compacts prepared by slip casting

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Abstract

Porous titanium compacts were fabricated using a slip casting technique. The slip casting process is low cost and has the advantage of producing green compacts with open pores. After final sintering the retained porosity gives the material a relatively high permeability. The organic compounds forming the binder and plasticizer are two major components in the slip casting process, which confer binding strength to the powder particles and flexibility in the green compact. In this paper, the effect of the total amount of binder and plasticizer dry weight percent (dw.%) (1.6 dw.% – 8.0 dw.%), when added in a 1:1 ratio, on the properties of porous titanium compacts was investigated. This was done by measuring the gas permeability, pore size and tensile strength of sintered titanium compacts after sintering at 1000°C for 2 hours. More importantly, due to the sensitivity of titanium to oxygen and carbon content, the amount of these impurities remaining in the sintered compacts was also examined. It was found that the maximum content of organic compounds should not exceed more than 4.0 dw.%, otherwise the slip viscosity is too high for it to flow satisfactorily into the mold. The optimum amount of organic additives was found to be 1.6 dw.%, and this produced a compact with an open porosity of 26.3 vol.% and the least amount of residual carbon.

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Keywords: Slip casting; Porous titanium; Binder; Plasticizer; Sintering; Tensile property; Permeability

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1. Introduction

A number of techniques have been developed to fabricate porous metal products, such as space-holder techniques (Wen (2001)), freeze casting (Chino (2008), Yook (2008)), loose powder sintering (Cirincione (2002)), tape casting (Driscoll (2011), Rak (2006)), etc. Recently, it has been demonstrated that porous titanium products, fabricated by slip casting, are feasible (Xu (2013)). The binder formulation for this slip casting process consists of three organic components, namely a binder, plasticizer and a dispersant. The effect of a dispersant on the slip casting process has been investigated thoroughly (Xu (2012)). In the present work, a more in-depth study was undertaken to investigate the effect of the amount of binder and plasticizer on the porosity, mechanical properties and impurity content of porous sintered titanium products. In the slip casting process, different dimensions and shapes of products require a different level of handling strength to retain their shape in the green state. There is a positive proportional relationship between the binder and plasticizer content and the green strength of a slip cast compact (Hotza (1995)). This study is particularly important for fabricating porous titanium electrodes for a water disinfection process (Nath (2011)). Because the electrode is 120 mm in diameter, a green compact must have sufficient handling strength for transferring to further processing stages.

2. Experimental Approach

Commercially pure hydride – dehydride (HDH) titanium powder was used as a starting material. The powder had a mean particle size of 14 μm measured by laser analysis (Mastersizer, Malvern, UK). Dolapix CE64 (DP64; Zschimmer & Schwartz GmbH Co., Germany) was chosen as the dispersant for obtaining a deflocculated slurry, and polyvinyl alcohol (PVA, mw.13,000; Sigma–Aldrich, US) and polyethylene glycol 400 (PEG400; Fluka Chemie GmbH, Germany) were used as a binder and plasticizer, respectively. The prepared titanium slurry was poured into a plaster mold to cast into green compacts ($40 \times 40 \times 10$ mm^3). The green slip cast compacts were then de-bound at 320^{o}C for 2 hours and sintered at 1000^{o}C under a vacuum atmosphere (3×10-3 Pa) for 2 hours. Further details about the slip casting process have been previously reported (Xu (2013)).

To investigate the effect of the binder and plasticizer on the properties of porous sintered titanium compacts, slurries were prepared with four different amounts of organic additives, but kept in a 1:1 ratio. The amounts of organic additive were 1.6 dry weight percent (dw.%), 2.8 dw.%, 4.0 dw.% and 8.0 dw.%, respectively. The sintered porous titanium compacts were analyzed to determine their level of porosity and open porosity, carbon and oxygen content, permeability, pore size and tensile properties. The amount of porosity and open porosity in sintered compacts was measured using the Archimedes method after previously vacuum impregnating samples, overnight, with distilled water. Carbon and oxygen content were analyzed using a Leco combustion technique. The gas permeability was determined using a pore size distribution analyzer (GaoQ Functional Materials Ltd, China). Dumbbell shaped tensile test pieces were made from the sintered compacts by wire electric machining. The test pieces had a gauge length of 10 mm and were tested at a strain rate of 1 × 10-4 s-1 using an Instron tensile testing machine.

Table 1. The properties of sintered Ti compacts, including impurity content and pore size analysis

Samples	Porosity	Open Porosity	Permeability Coefficient (m^2)	Carbon	Oxygen	Max. pore throat (μm)	Avg. pore throat (μm)
1.6 dw.%	28.6%	26.3%	7.0×10^{-14}	0.05%	0.46%	5.6	1.3
2.8 dw.%	28.9%	24.1%	7.8×10^{-14}	0.09%	0.47%	6.6	1.3
4.0 dw.%	29.3%	27.3%	7.2×10^{-14}	0.27%	0.49%	7.2	1.5