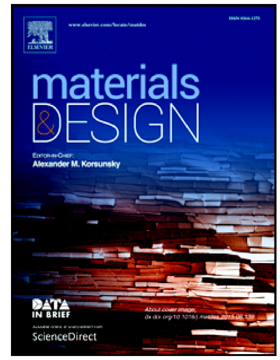
Accepted Manuscript



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PII: S0264-1275(16)31491-5
DOI: doi: 10.1016/j.matdes.2016.11.090
Reference: JMADE 2526

To appear in: *Materials & Design*

Received date: 24 August 2016
Revised date: 12 November 2016
Accepted date: 23 November 2016

Please cite this article as: Sakkadech Limmahakhun, Adekunle Oloyede, Kriskrai Sitthiseripratip, Yin Xiao, Cheng Yan , Stiffness and strength tailoring of cobalt chromium graded cellular structures for stress-shielding reduction. The address for the corresponding author was captured as affiliation for all authors. Please check if appropriate. Jmade(2016), doi: 10.1016/j.matdes.2016.11.090

Stiffness and strength tailoring of cobalt chromium graded cellular structures for stress–shielding reduction

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Abstract

The use of cobalt chromium (CoCr) in orthopaedic joint replacement shields the peri-implant bone stress, contributing to a premature loosening of the implants. In order to reduce the need for revision surgeries, light weight implants with tailored functionalities need to be developed. In this study, the compressive mechanical properties of laser-melted CoCr cellular structures with a pillar octahedral architecture [$0^o \pm 45^o$] were investigated. Four types of graded cellular structures, based on grading orientations along radial and longitudinal planes, were manufactured using selective laser melting techniques. The cellular structures in this study have the mechanical properties (E = 2.3–3.1 GPa, σ = 113–523 MPa) compatible with bone structures. Grading a porosity of the CoCr cellular structures provides a greater stress transfer to the proximal peri-implant area. The axially graded cellular structures demonstrated significant reduction of the peri-implant stress shielding. Incorporation of CoCr graded cellular structures into a structure like femoral stems is expected to have the potential to reduce the revision surgeries.

Keywords: Functionally graded cellular structures; Selective laser melting; Stress shielding; Mechanical properties; Cobalt chromium.

1. Introduction

Metallic cellular structures have been attractive for application in orthopaedic bone implants, since the porous architecture promotes bone anchorage and provides suitable stiffness [1]. On the other hand, dense metals such as those used for total hip replacement (THR), are often too stiff and can shield the adjacent bone tissue and cause loosening of the implants [2]. Selective laser melting (SLM) techniques are able to produce 3D cellular structures through printing of layered structures based on computer aided design (CAD) [3-5]. During SLM, metallic powder is melted by a scanning laser beam [5], featured by excellent reproducibility and efficiency [6].

Recently, the mechanical properties of titanium (Ti) alloys fabricated with SLM have been extensively studied under static and fatigue loadings [3, 5, 7-11]. Although Ti cellular structures have similar stiffness as bone tissues, fatigue is still a technical issue, which mainly resulted from poor design of the internal architectures [3, 12]. It is desirable if the mechanical