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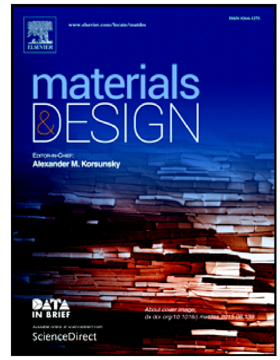

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Mimicking the loading adaptation of bone microstructure with aluminum foams

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Abstract

Nature has always been considered as a source of inspiration for scientists and engineers to create or mimic new materials with interesting properties. In this study, we draw inspiration from the loading adaptation of trabecular bone microstructure, which exhibits a graded distribution of porosity and cell size, with axially elongated cells. Using conventional foaming processes, we designed, manufactured and tested two different types of bone-inspired aluminum closed cell foams, aimed at mimicking the loading adaptation feature: the first type, characterized by a directional gradient of pores (i.e. along the length of the specimens) and the second type, characterized by elongated pores by hot rolling process. Micro-Computed Tomography (μCT) is used to compare the morphological properties of aluminum foams and those of bones. Geometry-based Finite Element (FE) models are built from the μCT images and validated by means of experimental data. Using image analysis techniques, virtual models have been created to expand the range of data and get further insight into the structural behavior of the material. This study shows that closed cell aluminum foams can be produced with biomimetic uniaxial mechanical properties in the low strain regime, by controlling their relative density and the axial orientation of cells.

Keywords: Cellular Materials, Closed-cell Aluminum Foam, Graded Pore Distribution, Elongated Pore Distribution, Micro-FE Simulation, Bovine Trabecular Bone, Biomimicry.

Nomenclature

C_0 [GPa]	Elastic Modulus of as-cast aluminum	OD [mm]	Outer Diameter of Cylindrical Samples
C_m [GPa]	Elastic Modulus at the microscopic level	SMI [-]	Structural Material Index
C_a [GPa]	Apparent Macroscopic Elastic Modulus	St.Sp.[mm]	Strut Spacing
DA [-]	Degree of Anisotropy	St.Th [mm]	Strut Thickness
E [%]	Strain	TV [mm^3]	Total Apparent Volume
$E_{y0.2}$ [%]	Yield Strain	U [MJ/mm^3]	Deformation Energy
E_{ult} [%]	Ultimate Strain	V [mm^3]	Solid Volume of sample
FS [mm^2]	Foam Surface	Σ [MPa]	Stress
L[mm]	Axial Length of Samples	$\Sigma_{y0.2}$[MPa]	Yield stress
M **[-]**	Fabric Tensor	Σ_{ult} [MPa]	Ultimate stress
m_i [-]	Eigenvalues	ρ_p [-]	Porosity
$\mathbf{m_i}$	[-]	Eigenvectors	ρ_s [-]
MIL [-]	Mean Intercept Length		

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