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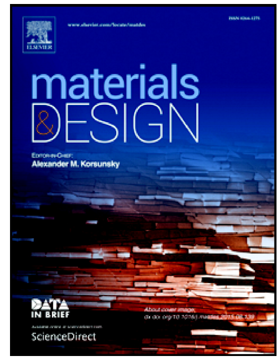

Bio-inspired method based on bone architecture to optimize the structure of mechanical workspieces

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Title

Bio-inspired method based on bone architecture to optimize the structure of mechanical workspieces

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Abstract

Nowadays, additive manufacturing processes greatly simplify the production of openwork workpiece providing new opportunities for workpieces design. Based on Nature knowledge, a new bio-inspired workpiece structural optimization approach is presented in this paper. This approach is derived from bones structure. The aim of this method is to reduce the workpiece weight maintaining an acceptable resistance. Like in bones, the porosity of the part to optimize was controlled by a bio-inspired method as function of the local stress field. Shape, size and orientation of the porosities were derived from bone structure; two main strategies were used: one inspired of avian species and other inspired of terrestrial mammalian. Subsequently, to validate this method, an experimental test was carried out for comparing a topological optimization and the proposed bio-inspired designs. This test was conducted on a beam part in 2.5D subjected to a static three-point bending with 65% of density. Three beams were manufactured by 3D metal printing: two bio-inspired beams (terrestrial mammalian and avian species) and the last designed using a topological optimization method. Experimental test results demonstrated the usefulness of the proposed method. This bio-inspired structural optimization approach opens up new prospects in design of openwork workpiece.

Keywords

Bio-inspired optimization; Functionally graded materials; Topological optimization; 3D printing; Bone structure

Nomenclature

p pattern size
c porosity mean radius
e minimal distance between two porosities
a Principal ellipse axis
b Second ellipse axis
h characteristic structure length
E Young modulus
ν Poisson ratio
ρ_f Volume fraction
σ_1 Principal tensile stress
σ_3 Principal compression stress

1 Introduction

For each lifestyle, nature takes into account the constraints imposed by the environment to create optimized biological systems in term of mechanical resistance, mass and lifespan. Then, porous materials appeared in lots of systems in nature. Bone structure is the result of millions of years of evolution. Thus, the bone is still considered as one of the most efficiency structure architecture (cortical and trabecular). It has been the subject of many research studies to understand the driving parameters of its micro-structure. Bone cells are able to measure the local stress acting as a bio-mechanical sensor. Bone material structure and its distribution are adapted by collaborative work of osteocyte and osteoblast cells versus the mechanical load [1]. Trabecular bone micro-structure aligned in the principal stress directions (Wolff's law)[2] is generated by this natural adaptation (Fig .1). Different volume fractions are induced by the local stress level. The obtained result is a combination of plate-like elements and rode-like elements [3]. Finite element analysis performed on the

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