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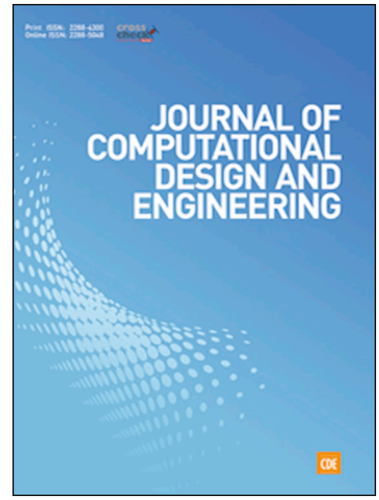

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Local microstructure-based material performance and damage in design and finite element simulations of cast components

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Abstract

A novel approach to incorporate local microstructure-based material performance into finite element method (FEM) simulations of cast components is presented. By adopting perspectives from natural designs as dinosaur skulls and trees, the discipline-wide approach enables accurate prediction of damage in structures based on a heterogeneous distribution of sub-scale features. It is shown that heterogeneous damage tolerance dictates the performance and failure of cast aluminium, and simulations are compared with experimental results of heterogeneous tensile samples using digital image correlation (DIC). The numerical application of the approach in the industrial product realization process of an industrial casting is demonstrated, and the applicability of the approach to understand the behaviour and failure of natural as well as synthetic structures is discussed.

Keywords

Casting and solidification; Modelling and simulation; Component casting; Casting process simulation; Finite element simulations; Damage; Strain energy density.

1 Introduction

Although trees [1], eyes [2], the heart [3], dinosaur skulls [4] and biscuits [5] may seem essentially different from aluminium castings [6] and concrete structures [7], they all share the common attribute of containing a heterogeneous distribution of microstructural features and properties that dictate their behaviour and performance. In biological and physiological structures such as trees [1], eyes [2,8], teeth [9], bone [10], the aortic arch [3] and the skin [11] and skulls of humans [12] and animals [13,14], the heterogeneous distribution is tailored on multiple scales [15] including nano-scale [16] to enable extraordinary performance. In synthetic structures, sub-scale heterogeneities due to variations in processing conditions and composition are present in areas such as food [5], cast [6] and forged [17] automotive parts, injection moulded thermoplastic [18] as well as concrete [7] structures.

Aluminium alloys, as most metallic alloys, solidify through the nucleation and growth of phases in a non-isothermal transformation, where the composition and local cooling rate controls phase selection and the time available for growth of the different phases and thus the morphology and refinement of the phases formed [19]. Simultaneously, chemical and rheological liquid-solid interactions lead to local phenomena such as segregation of elements