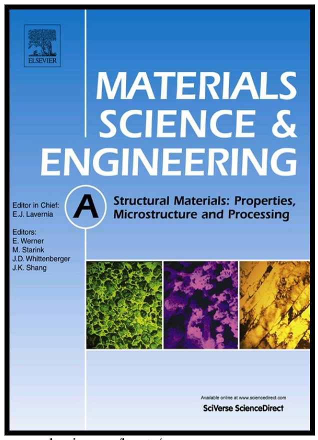

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Characterization and modeling of the mechanical behavior of high silicon ductile iron

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Abstract

This paper investigates the effect of the solidification conditions and silicon content on the mechanical properties of ductile iron and presents empirical models for predicting the tensile behavior based on the microstructural characterizations. Two ductile iron grades of GJS-500-7 and GJS-500-14 were cast with silicon content of 2.36 and 3.71%, respectively. The cast geometry consisted of six plates with different thicknesses that provided different cooling rates during the solidification. Microstructure analysis, tensile and hardness tests were performed on the as-cast material. Tensile behavior was characterized by the Ludwigson equation. The tensile fracture surfaces were analyzed to quantify the fraction of porosity. The results showed that graphite content, graphite nodule count, ferrite fraction and yield strength were increased by increasing the silicon content. A higher silicon content resulted in lower work hardening exponent and strength coefficient on the Ludwigson equation. The results for 0.2% offset yield and the Ludwigson equation parameters were modeled based on microstructural characteristics, with influence of silicon content as the main contributing factor. The models were implemented into a casting process simulation to enable prediction of microstructure-based tensile behavior. A good agreement was obtained between measured and simulated tensile behavior, validating the predictions of simulation in cast components with similar microstructural characteristics.

Keywords: Spherical graphite iron, component casting, silicon content, Ludwigson equation parameters, casting simulation.

1 Introduction

Microstructural characteristics of cast irons such as graphite shape and distribution, as well as the metal matrix microstructure depend on chemical composition, casting process, e.g. cooling condition [1, 2]. For ductile iron with nodular graphite particles, the overall graphite volume, area fraction of the nodular graphite (nodularity), number of nodules per unit area (nodule count), graphite size and the matrix microstructure, are strongly influenced by both solidification conditions and alloying element additions[3, 4]. The microstructural characteristics greatly affects mechanical properties of ductile iron [5, 6]. In addition, the amount and type of alloying elements can affect the mechanical properties by changing the metal matrix phases (e.g. changing the amount of ferrite/pearlite), nodularity and nodules counts [4].

Local solidification rate varies in a cast component due to variations in section thickness and dissipation of heat in different regions of the mold. In the case of ductile iron, this leads to variations in microstructure (e.g. graphite distribution, ferrite content, and pearlite fraction) in different parts of a component, resulting in variation of mechanical properties on mesoscale level. This variation influences the mechanical response of a component in its application and must be considered in the design of cast components [7, 8]. This emphasizes the need for investigation and quantification of the mechanical properties of ductile iron for different section thicknesses. In an extension, the investigations will also increase the quality of multiscale modelling as the local loads could be better described [9].