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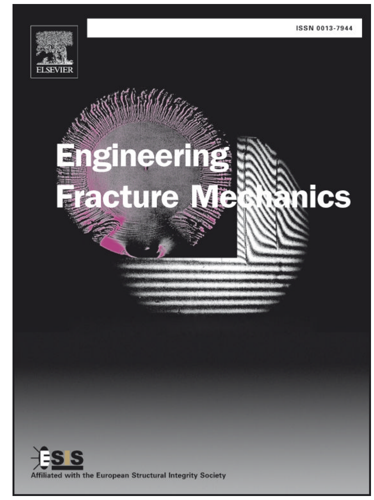


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# Long crack growth and crack closure in high strength nodular cast iron

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**Abstract**

In the context of wind turbines, highly stressed structural components are often made of EN-GJS-700-2. This high strength nodular cast iron grade is characterized by an almost purely pearlitic matrix resulting in a comparatively low toughness. Therefore and due to inevitable casting defects, a fracture mechanical strength assessment, additionally to a conventional one, is often required. However, it lacks a detailed characterisation of EN-GJS-700-2 in terms of fracture mechanical material parameters. Thus, the objective of this study was to derive a comprehensive description of long crack growth for this cast iron grade.

For this purpose, profound experiments were performed on raw material taken from a real planet carrier. Crack growth was analysed under varying loading conditions whereby the impact of the stress ratio and the maximum stress intensity factor was of special interest. The threshold behaviour was described in terms of two threshold values. Relevant crack closure mechanisms were analysed in detail: plasticity, oxidation and surface roughness. The latter one was identified as the most dominating mechanism. Three different approaches to describe crack closure were derived. Its integration into a crack growth law yielded a uniform description in terms of an effective stress intensity factor. To describe crack growth in a less complex way, two other crack growth laws, based on a two-parameter approach respectively on the maximum stress intensity factor, were derived.

*Keywords: cast iron; fatigue crack growth; threshold; crack closure; fracture surface roughness*

## 1. Introduction

The beginnings of a systematic engagement in damage tolerant design date back almost one century. In the past decades, the materials predominantly investigated were a consequence of the particular application and the associated necessity for damage tolerant design. Next to steel, aluminium and titanium alloys were the main focus of interest. Not until the 80s, cast iron was systematically studied from a fracture mechanical point of view. Speidel [1] analysed crack growth and unstable fracture for a broad variety of cast iron alloys. Concentrating on nodular cast iron, Bulloch [2,3] investigated the influence of varying ferrite respectively perlite content. Conducting crack growth experiments for nine different stress ratios, he examined extensively its impact on crack growth and threshold behaviour. Likewise, Jen et al [4,5] investigated the stress ratio effect on crack growth for a ferritic-pearlitic nodular cast iron and completed their examinations with fractographic analyses. Similar investigations were performed by Griswold [6], though concentrating on crack closure in a comparable cast iron grade. Crack closure's impact on crack growth was further analysed by Tokaji et al [7], differentiating between four different matrix compositions in case of nodular cast iron. Especially during the last two decades, austempered ductile iron [8–11] and purely ferritic EN-GJS-400-15 [12,12] or -18(LT) [13–16] were the focus of fracture mechanical investigations.

Thereby, the latter ferritic nodular cast iron has often been discussed in the context of wind energy plants. Most of the nacelle's structural components, like for example rotor hub, torque arm, bearing housings, or machine frame, are manufactured out of this ductile cast iron. It guarantees a required strength combined with sufficient toughness, even in cold climate environment (down to – 40° C [17]). However, for highly stressed components, like the planet carrier, the high strength cast iron EN-GJS-700-2 is the construction material of choice.

Its microstructure is characterized by an almost purely pearlitic matrix resulting in a comparatively low toughness. Therefore and due to inevitable casting defects, a fracture mechanical strength assessment, additionally to a conventional one, is often required. For a planet carrier manufactured out of EN-GJS-700-2, the procedure is documented in a guideline [18]. Case studies to initial assumptions are published in [19,20]. However, it lacks a profound basis of fracture mechanical parameters to perform an assessment with this construction material. Most of the pearlitic nodular cast irons investigated [1–7] have a residual content of ferrite (often arranged around the graphite spheres in a bull's eye structure). Therefore, the corresponding results are not transferable to the purely pearlitic EN-GJS-700-2.