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NUMERICAL INVESTIGATION OF LOW CYCLE FATIGUE MECHANISM IN NODULAR CAST IRON

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Abstract: The failure mechanism in ductile cast iron under static loading is nucleation, growth, and coalescence of voids. It is known from the literature that elastic - plastic porous materials under strain controlled cyclic loading show an increase of void volume fraction called void ratchetting effect. From this observation, we suggest that void ratchetting is the relevant mechanism for low cycle fatigue in nodular cast iron as well. The low cycle fatigue process in the microstructure of ductile cast iron has been simulated cycle by cycle using unit cell models. The strain-life approach for fatigue is followed in this work. The matrix material behavior is modeled as an elastic – plastic one. From the simulations, void ratchetting is identified as a potential mechanism of low cycle fatigue in nodular cast iron which finally leads to failure. The lifetime of different load ratio and different matrix material behavior is extracted from the simulations. The simulated strain-life curves are compared with experimental data from literature.

Keywords: nodular cast iron, low cycle fatigue, strain-life approach, void ratcheting, strong effect of shape of particle

1. Introduction

Nodular cast iron (NCI) or ductile cast iron is an iron-carbon alloy. In NCI, the shape of graphite particles is nearly spherical that makes NCI's properties unique as compared to the other types of cast iron. NCI has mechanical properties like steels. However, in comparison to steels, NCI reduces manufacturing costs. For these reasons, NCI is widely used in transportation, nuclear and energy industries. A few examples of the application of NCI are gearboxes and crankshafts in automobile industry, wind turbine rotor hubs in energy industry and nuclear storage and transportation casks [1].

The properties of NCI are dependent on the material's microstructure, the form, size, and distribution of graphite particles and the defects present in the matrix due to the casting process. A ferritic matrix leads to ductile behavior of NCI, whereas a pearlitic matrix not only increases the strength but also brittleness. The combination of two phases shows the intermediate material behavior.

The material fatigue under cyclic loading is the relevant damage cause in most practical applications since most structural components are exposed to alternating service loads. Thus, a better understanding of fatigue failure is very important. Murakami [2] has mentioned previous studies related to the effect of shape and size of graphite nodules and microstructure on the fatigue strength of NCI. No information is mentioned regarding extremely low cycle fatigue in NCI.

To gain information about low cycle fatigue (LCF), experimental and computational approaches can be used. With significant advancements in the computational power, the simulation approach becomes more popular and efficient to understand the interaction between microstructure and material behavior [1].

As NCI is mostly used in high cycle fatigue (HCF) applications, there is scarcity of literature reporting on extremely low cycle fatigue (ELCF) of NCI. Komotori et. al [3] have experimentally observed void growth and coalescence in the ferritic NCI material. The schematic diagram of this process is shown in

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