Séminaire: Modelling microstructural effects in fatigue of metals

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A multi-mechanism model for fast HCF characterization of alloys in the presence of process-induced pores

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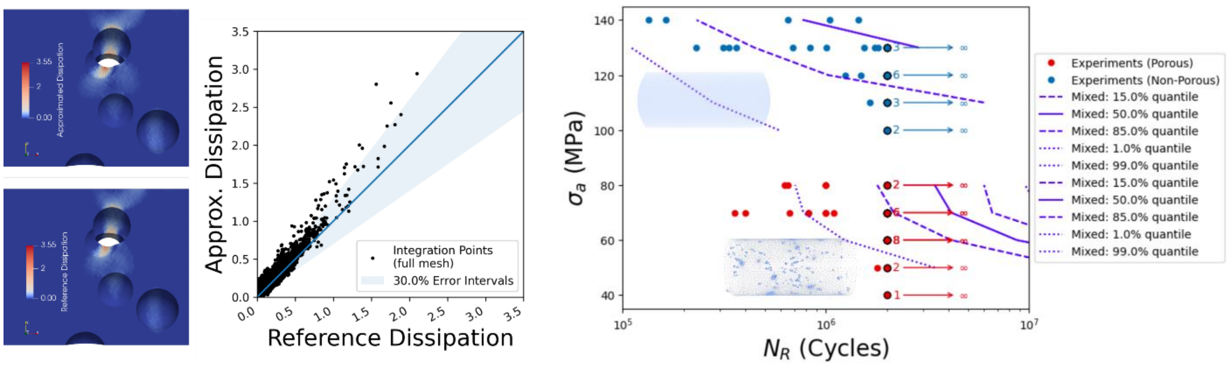
KEYWORDS: Fatigue life prediction, Machine learning, Model reduction, Infrared thermography

ABSTRACT:
The presence of process-induced meso-scale pores, typically present in a variety of cast and additively manufactured alloys, typically leads to a low fatigue limit and an important dispersion related to the distribution of pores. On the other hand, the closure of these pores via hot isostatic pressing improves the fatigue life, however, a scatter in fatigue life still exists due to inherent micro-heterogeneity like silicon precipitates. Therefore, a new fatigue model with two mechanisms – a stochastic approach for the micro-plasticity based on a separation of scales [1], and a criteria using Chaboche-type laws for plasticity around the pores, is proposed. The finite element method is used to take into account the complex morphology of pores, and a new Neuber-type method for fast approximation of the full-field plasticity in structures [2] was implemented. The parameters of the multi-mechanism model may be obtained via a maximum likelihood estimate on a combination of fatigue experiments and thermographic data.



(a) (b)

Fig. 1. (a) Results of the Neuber-type method for fast approximation of the dissipation in structures with pores (b) Fatigue life predictions for specimens with or without complex pores, using a maximum likelihood estimate on experimental fatigue data for parameter identification

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Modelling the influence of clustered defects on HCF properties of Ni-based superalloys

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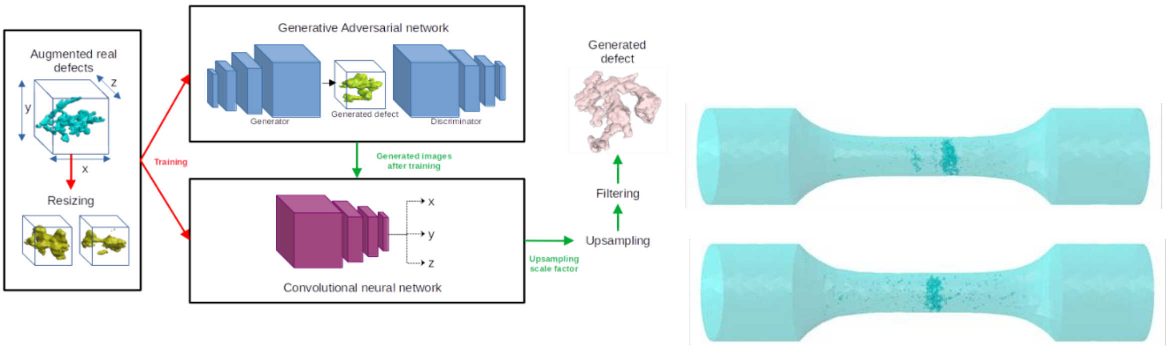
KEYWORDS: Ni-based Superalloys; HCF; Deep learning; X-ray Tomography; Casting defect

ABSTRACT:

Casting defects like shrinkages and pores are very detrimental for material's High Cycle Fatigue (HCF) performance [1]. It is known that defect's size and their location from free surface are the most important parameters to take into account regarding HCF properties. However, this conclusion is questionable in the case of clustered defects: specimen lifetime seems to also depend on other characteristics of the defect cluster. The distribution of defect size in an individual cluster is found to be dependent on clustered defects volume and thus influencing the ASTM grades of the material. The gradient associated to the same isolated defect is modified in the presence of cluster further modifying the fatigue predictions via non-local approaches like volumetric homogenization.

However, this type of analysis requires a very large number of three-dimensional observations of casting defects dataset which is impractical and very expensive. Therefore, in this work, a Generative Adversarial Network (GAN) is integrated with Convolutional Neural Network (CNN) to generate synthetic defects (see figure 1.a) and are distributed in material space with the aid of spatial point pattern analysis of defects to generate synthetic microstructures that mirrors real specimens as shown in figure 1.b [2]. Four Inconel 100 and nine Rene 125 specimens tomographed via X-Ray Computed Tomography have been used to study the spatial point pattern of defects and to train Deep Neural Networks (DNN). Spatial point pattern analysis helps to understand how the defects are distributed in material space [3] whilst GANs generate synthetic defects which can be placed randomly respecting the statistics of real specimens.

These N synthetic samples are submitted to numerical simulations to exploit the fatigue behavior via non-local approaches, see figure 2. Furthermore, some of the important features of defect clusters such as, defect volumes, cluster thickness, density of defects in a cluster etc., are controlled to analyze the influence on stress gradients in the synthetic microstructures.



a. *b.*

Fig. 1 a. Representation of DNN to generate synthetic defects b. Examples of few generated synthetic microstructures

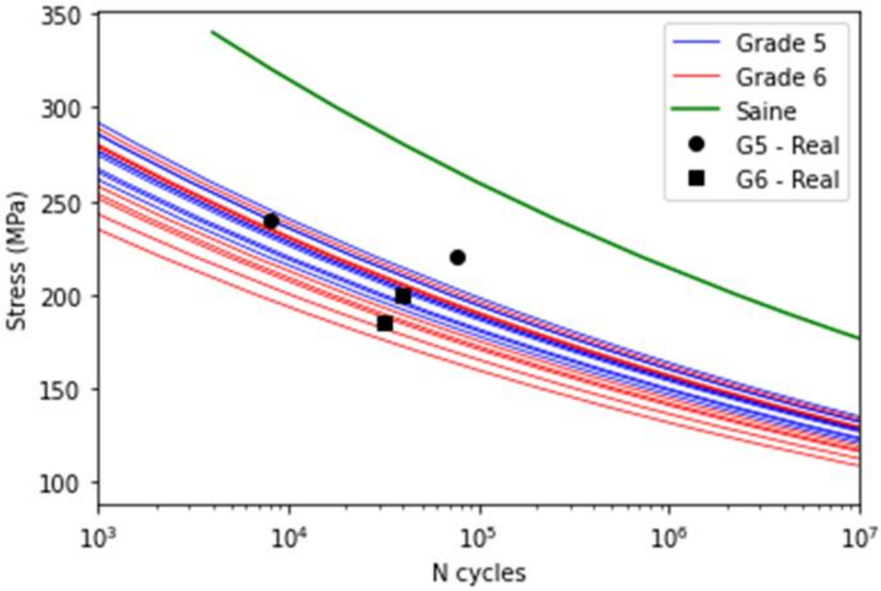


Figure 2. Wohler curves of synthetic microstructures

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