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EDITORIAL

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Fatigue & Fracture of Engineering Materials & Structures Virtual Special Issue: Data science and machine learning for fatigue and fracture assessment

Fracture mechanics and material fatigue are complicated scientific areas of interest that are vitally important for reliable industrial design. Destructive experimental studies are one of the most valuable tools of scientists and engineers, which are used to understand these subjects. However, they are known to be both time-consuming and costly. In addition, the results of these experiments are often sets of data that require post-processing and statistical analyses by experts to be practically useful in the industry.

As the industry strives for more complicated and efficient designs, data science becomes an essential part of fracture mechanics and fatigue studies due to the increasingly large amount of data that are required to be processed. With the recent developments in machine learning, these difficult tasks are overcome with the assistance of computer algorithms. From statistical observations to optimization of numerical processes, machine learning algorithms are quickly becoming more prevalent in structural durability investigations.

In this regard, the main objective of the present special issue is to highlight the rising significance of using data science and machine learning alongside material fatigue and fracture mechanics. State-of-the-art articles presented in this special issue will hopefully encourage even more future studies on this interdisciplinary topic.

The present Virtual Special Issue (VSI) "Data Science and Machine Learning for Fatigue and Fracture Assessment" consists of 11 papers from invited authors. These papers focus on the use of data sciences in structural durability investigations with a particular emphasis on material cyclic behavior and fractures.

Tomczyk and Seweryn[1] presented an experimental study of creep rupture and low-cycle fatigue (LCF) of EN-AW 2024 aluminum alloy with and without preliminary damage. The preliminary creep damage of two different strain values was dealt at elevated temperatures of 100°C, 200°C, and 300°C. A damage accumulation model was proposed for creep at different temperatures, with the growth of the damage state variable dependent on the current value of axial stress and on the growth of plastic strain.

Yang et al.[2] used the master S-N curve method to determine the critical failure mode in welded U-rib to deck connections in orthotropic bridge deck structures. The proposed method included additional considerations and was used to quantitatively determine the effects of weld penetrations and test loading conditions on failure mode development.

Vantadori et al.[3] investigated a procedure for fatigue strength assessment of metals containing solidification defects. The fatigue behavior of a ductile cast iron (DCI) characterized by a relevant micro-shrinkage porosity was investigated. The procedure consists of a statistical method deriving from extreme value theory, the $\sqrt{area}$-parameter model, and the multiaxial critical plane-based criterion. The procedure allows significantly easier defect content analyses by using machine learning techniques.

Gan et al.[4] proposed a data-driven model for fatigue life prediction under mean stress effects. In order to simulate the complex correlations among mean stress levels, material properties, and fatigue lives, multiple independent extreme learning machines are integrated into the model with distinct neural network configurations. Extensive sets of experimental data were used for model training and evaluation. The proposed model managed to achieve high accuracy and good stability in fatigue life prediction under mean stress loading conditions.

As an alternative to conventional stress concentration factor-based fatigue assessment approaches, Braun and Kellner[5] proposed a machine learning technique that estimates the fatigue failure locations and the number of cycles to failure. For this purpose, comparisons of 621 fatigue tests of small-scale butt-welded joints were presented. The study utilized gradient boosted trees with the SHapley Additive exPlanation framework to identify influential features and their interactions.

Zhao et al.[6] proposed a weld sizing criterion in terms of two weld leg sizes and weld penetration to avoid root failure in load-carrying cruciform fillet welded joints. The mechanical-directed data augmentation technique was used to obtain the weld sizing criterion. The traction-stress-based method was utilized to determine the fatigue failure mode and was statistically compared with 372 experimental fatigue data.

Livieri and Tovo[7] examined the effects of the actual weld profile on the fatigue behavior of welded joints via the implicit gradient approach. FE analyses were based on the three-dimensional scans of the welded joints, and a comparison was made with experimental data from the literature.

Cortivo et al.[8] estimated the wheel loads of a race car using four approaches: A geometric matrix (GM) method, a feedforward neural network (FNN) approach applied to the fully instrumented suspension (FIS), an FNN approach involving a reduced number of sensors and an inertial measurement unit (IMU), and a linear modeling approach (LM). The FNN-based methods have been trained via suspension signals and validated by comparing the estimated loads with those estimated by the GM method. The results show that the FNN approaches are effective for the estimation of the wheel forces.

Soyer et al.[9] used artificial neural networks and fatigue data from the literature to estimate the low cycle fatigue parameters and fatigue lives of high-strength steels. The accuracy of the estimations was evaluated based on the choices of activation functions, epoch numbers, training functions, elapsed times of training functions, and the number of hidden neurons.

In order to validate adequate specimen sizes, Yang[10] investigated the distribution of residual stress of the substructure model and small coupon specimens in orthotropic steel bridge structures. Blind-hole drilling and X-ray diffraction methods were used to ascertain the longitudinal and transverse residual stresses and evaluate the effects of the cutting process. The width-to-thickness ratio of small coupon specimens was determined as 6–6.25 and was sufficient to capture the effects of stress triaxiality induced by the residual stress.

In order to present a consistent fatigue assessment approach of powder metallurgy components, Leininger et al.[11] developed and applied five machine learning-based approaches. An extensive data set that consists of 828 test series was used in the study and the proposed method managed to achieve accurate fatigue life estimations.

As the guest editors of this special issue, we would like to thank all contributors for their valuable additions. We are grateful and honored to be part of this special issue alongside many authors who worked tirelessly to share their knowledge with the community. In addition, we would also like to thank the reviewers for their invaluable comments and suggestions to improve the quality of each submission. We would also like to thank Fatigue & Fracture of Engineering Materials & Structures and Wiley for making this special issue possible.

Finally, we would like to address and acknowledge the unfortunate 2023 Türkiye-Syria Earthquake that occurred during the writing of this editorial. We would like to respectfully express our deep sadness and grief. We extend our condolences and best wishes to all that were affected.

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