A Bayesian Regularization Neural Network Model for Fatigue Life Prediction of Concrete

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Abstract

The fatigue life of concrete is affected by many interwoven factors whose effect is nonlinear. Because of its unique self-learning ability and strong generalization capability, a neural network model is proposed to predict concrete behavior in tensile fatigue. Firstly, the average relative impact value was constructed to analyze the importance of parameters affecting fatigue life, such as the maximum stress level S_{max}, stress ratio R, failure probability P, and static strength f. Then, using the backpropagation neural network improved by Bayesian regularization, S-N curves were obtained for the combinations of R=0,1, 0,2, 0,5; f=5, 6, 7MPa; P=5%, 50%, 95%. Finally, the tensile fatigue results obtained from different testing conditions were compared for compatibility. Besides utilizing the valuable fatigue test data scattered in the literature, insights gained from this work could provide a reference for subsequent fatigue test program design and fatigue evaluation.

Keywords: concrete; fatigue life prediction; neural networks; Bayesian regularization.

1 Introduction

As a complex multi-phase composite material, concrete exhibits significant discreteness in fatigue life [1]. Moreover, since the mapping relationship between fatigue life and its influencing factors is nonlinear, fatigue life estimation has become the emphasis of concrete fatigue research [2]. The conventional method of analyzing fatigue life fits fatigue test data to a specific function relationship. The parameters considered in the fatigue life equations initially contained only the stress level S. Later, the stress ratio R, the loading frequency n, and the failure probability P were gradually integrated for practical applications. Despite their extensiveness and complexity, the proposed equations cannot be applied to all fatigue analyses and are difficult to ensure accuracy [3].

The artificial neural network, which is automatically approximated from the training data [4], does not need to make assumptions about the function form. It is feasible to improve the applicability and prediction accuracy of multi-parameter fitting of fatigue life. Lu and Song [5] used four factors of S_{max}, R, n, and P to train the backpropagation neural network (BPNN) and realized the fatigue life prediction of concrete. Xiao et al. [6] developed a portable fatigue life prediction model, using R and S_{max} as input, with engineering application value. Abambres and Lantsoght [7] used the minimum stress level S_{min}, the geometric mean of fatigue life, and the concrete compressive strength as inputs. They obtained the S_{max} as output for structural design and evaluation purposes. Statistically, the proposed model predicts more accurately than the code equations.

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