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(都市イノベーション学府 Graduate School of Urban Innovation)

論 文 要 旨
Summary of Dissertation

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専　攻 Department	Graduate School of Urban Innovation
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論文題目 Title	Development of Ultra-Low Cycle Fatigue Life Prediction Model for Structural Steel Surfaces
和訳または英訳 Translation (J->E, or E->J)	構造用鋼材表面における超低サイクル疲労寿命予測モデルの構築

With the occurrence of extreme events such as the Northridge earthquake of 1994 and the Kobe earthquake of 1995, a number of structural steel members failed after the occurrence of local buckling. Under strong cyclic excitations, such as resulting from devastating earthquakes, economically built steel structures are anticipated to partially experience plastic deformation. When the structures undergo seismic events of higher magnitudes, they experience cyclic loading reversals of larger amplitudes. This results in concentrated larger plastic deformation, which prompts the formation of cracks, and ultimately failure occurs within a smaller number of loading cycles. The fatigue life resulting from less than 200 loading cycles is referred to as ultra - low cycle fatigue (ULCF) life and it is the dominant failure mode for the structures undergoing severe earthquakes. In addition to larger amplitude loading, structural steel members also experienced higher loading rates loading during the Kobe earthquake of 1995. Moreover, abrasive blast cleaning is usually done on steel surfaces before the application of various protective coatings, which results in the generation of rough surfaces and significantly affects fatigue strength. Therefore, the parameters of surface roughness, loading frequency, and loading amplitudes can have a significant impact on the ULCF life. However, the coupled effect of these factors on the ULCF life is missing in the existing research, which raises concerns about the efficacy and accuracy of the existing fatigue evaluation methods. Therefore, to guarantee the safe design of structural members, a more reliable ULCF model incorporating the effect of all these influential parameters is desirable.

The main objective of this dissertation is to develop a novel ULCF life prediction model incorporating the effects of surface roughness, loading frequency, and loading amplitudes for SM400 structural steel. A total of 61 experiments were conducted on test specimens comprising 59 fatigue tests and 2 tensile tests. The geometry of fatigue specimens was designed such that the deformation is localized at the central region. The central region of the fatigue specimens was blast cleaned by varying the machining parameters to produce five levels of surface roughness i.e., 20, 40, 60, 80, and 100 μm. A displacement-controlled loading protocol was employed under varying loading amplitudes ranging from 2 to 5 mm and varying loading frequencies ranging from 0.005 to 5 Hz to target the phenomenon of ULCF fracture initiation. The load-displacement curves, energy dissipation curves, and load degradation curves are used for checking the effects of variable parameters on ULCF life. Surface height data obtained from the laser scanning technique is used for direct evaluation of surface strain by employing the surface curvature method. Based on extensive experimental data, a modified Coffin-Manson (MCM) model incorporating the impacts of surface roughness, loading frequency, and loading amplitude is developed. Constant amplitude loading tests are

used for the development of the proposed model by conducting the regression analysis. By comparing the experimental and predicted fatigue life under the constant as well as variable amplitude loading tests, the accuracy of the proposed model is validated. Ultimately, the Artificial neural network (ANN) technique is applied for the development of an ANN-based model to accurately predict the ULCF life. For that purpose, a feed forward back propagation neural network is designed for the development of a number of models by employing the cross-validation technique. All the models are trained, validated, and tested by taking surface roughness, loading amplitude, and loading frequency as inputs and the experimental fatigue life as an output. Based on the comparison of statistical parameters, a generalized ANN-based model is developed and the respective synaptic weights and biases of neurons are extracted. Finally, the extrapolation ability of the proposed ANN model is checked and the prediction accuracies of both the MCM model and ANN-based model are compared. It is concluded that the ANN-based approach gives better prediction accuracy than that of the developed MCM model.

The newly developed ULCF model is the first of its type and it can accurately evaluate the fatigue life by incorporating the coupled effects of surface roughness, loading amplitude, and loading frequency. It is anticipated that the work of this dissertation will be useful to find applications for improving the design guidelines for steel structures subjected to extreme loading conditions. Also, it can enhance the prediction accuracy of ULCF life in engineering practices.

4,000 字以内

Must not exceed 4,000 Japanese characters or 1,600 words.