Machine Learning Based Surface Crack Characterization Using Rayleigh Wave Signals

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ABSTRACT

Welding joints are widely used components in marine and offshore structures, particularly for metallic structures. They are easily exposed to fatigue failure under cyclic loading. It is therefore necessary to conduct a regularly non-destructive inspection for these structures during their life, especially for fatigue cracks before they reach a critical size. Among the many non-destructive methods, ultrasonic technique is one of the most efficient ways to monitor the growth of fatigue cracks. Ultrasonic Rayleigh waves are extensively used and particularly suitable for detection and sizing of surface cracks. These waves have the energy concentrated in a small layer at the surface and decayed with depth. With the feature of propagating near the free boundary and following the complicated curvatures, Rayleigh waves can provide insight to inaccessible area of other wave forms. Conventional ways using ultrasonic Rayleigh waves are: timing method which is based on the time taken for the wave to pass around the surface crack surface; time-of-flight diffraction technique which uses the elapsed time between the Rayleigh wave signals and crack-tip diffraction signals; and amplitude measurements which calculates the reflected/transmitted coefficients from signals in either time or frequency domain. However, the conventional ultrasonic techniques either have the limitation on the crack size they can measure or requires a complex interpretation to select damage features from the whole signals. It makes them time-consuming, challenging and highly rely on engineering experience and professional knowledge.

In order to address the above issues, an approach combining machine learning (ML) models with ultrasonic Rayleigh waves is proposed to measure the depth of the surface crack in this work. Considering the requirement of large training data for ML models and the scarcity of real defect data, numerical models of a plate structure with surface cracks of varying depths are first constructed to provide the training and validation datasets. The damage related features are selected and extracted from received signals in both time domain and frequency domain. These features subsequently serve as the input of ML models. Different ML models have been developed and compared with each other using the validation set. The model with the best prediction accuracy on validation can then be used to estimate the depth of the real fatigue crack. The highest prediction accuracy of depth measurement using the proposed approach is 90% on validation set. It is potential to realize an automated sizing of fatigue cracks in welding joints by further development of this machine learning based characterization method.

Keywords: Rayleigh wave, surface crack, feature selection, machine learning