Offshore & Dredging Engineering

Investigating the Behaviour of Acoustic Emission Waves near Cracks

During fatigue crack growth of metallic structures, acoustic stress waves are introduced into the material. These *acoustic emission* waves are the result of the sudden stress release during the nucleation of the crack surface. Using dedicated acoustic emission monitoring equipment, these waves can be recorded. When multiple sensors are able to pick up the waves of a certain fatigue crack growth step, the location of this crack can be determined by using the differences in time of arrival of the signals at these sensor locations. This localization is performed by the method of multilateration, which is the same method that is used to calculate the epicentre of earthquakes.

TU Delft and the 4D-Fatigue joint industry project will use acoustic emission to predict fatigue crack depth, in order to determine the crack growth rate in a multi-axial fatigue loaded test specimen. The location of the fatigue crack will be known, so sensors can be applied very close to it. This use of acoustic emission is unconventional due to the fact that most appliances focus on a much larger scale, since this is one of the advantages of this method. The accuracy goal which is set during this project is also far exceeding traditional use, aiming at a crack depth prediction with an error less than 1mm. Little literature on acoustic emission focuses on this close range, inducing the need for additional research.

The goal of this thesis is to perform finite element simulations, in order to determine the behaviour of acoustic emission waves in close proximity of the crack. This knowledge should be used to determine what accuracy values are achievable, and whether there are ways to improve on this accuracy.

The first step in order to achieve this goal was the simulation of a Hsu-Nielsen source, more commonly referred to as a *pencil lead break*. This is a very simple to perform acoustic emission source, and will serve to establish appropriate finite element simulation parameters. This simple first step is also convenient to establish the effect the acoustic emission monitoring equipment has on the obtained signals. The multiple filter steps which are performed by the hardware, and the frequency response of the sensor have a great influence on the signal. Pencil lead breaks were performed on a steel plate of 5mm thickness, at several distances of a sensor. Signals produced by the simulations were verified by the experimental signals in a range of 5mm-70mm, verifying the used simulation methods.

The next step was to simulate actual fatigue growth in the same steel plate of 5mm thickness. Experimental signals were attempted to be acquired during fatigue tests of the plate. The fatigue machine that was used however, turned out to produce high amplitude noise, making it not possible to obtain the desired signals. Since verification of the simulated signals would not be possible, several source models were investigated in order to simulate fatigue crack growth acoustic emission, comparing the localization results with each other. Localization using conventional methods were able to achieve an accuracy of 0.6mm. Using a new method of wave speed determination however, which makes use of the simulation results, the localization accuracy was improved to 0.4mm.

The final step was to perform a simulation of a specimen which is used by the 4D-Fatigue JIP. This *tubular specimen* contains flanges, which reflect inbound waves back to the sensors, potentially influencing the localization accuracy. The simulations however, concluded that these reflections arrive after the initial wave has passed. The effect on localization was found to be negligible. Localization using conventional methods was not found result in reliable data. This decrease in accuracy compared to the accuracy found in the 5mm plate, is attributed to the larger differences in travel distance the signals have, due to the 10mm thick body of the tubular specimen. Localization using the new speed determination method, resulted in a localization accuracy of approximately 1mm.

Although localization accuracy was found to be sufficient to satisfy the initial goal of 1mm, it should be noted that the localization was performed using an estimated noise amplitude value. Also, during these numerical simulations the sensor is exactly known, which is not the case during experiments, so additional location error should be taken into account. The work in this thesis does however describe multiple phenomena which influence the localization accuracy, and forms basis for further research to improve on it.

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