Development of a Simulation Model for Ultrasonic NDT Applications

Using a Physical Approach

Student

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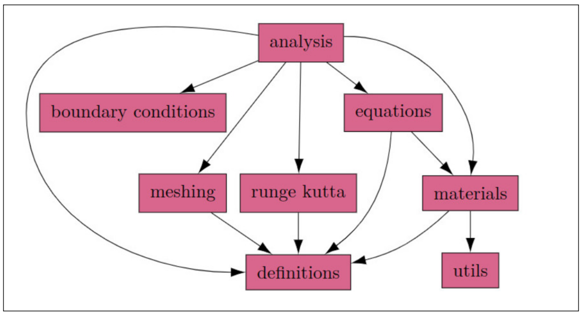
Introduction: Ultrasonic nondestructive testing (NDT) is a widely used method for inspecting welds from the inside without the need for cutting open the parts. These measurement systems use ultrasonic transducers to send pulses into the parts and receive the echoes of these pulses. With these measurements, computer algorithms can automatically detect contaminants within the welds, ensuring structural integrity. To further improve the accuracy of these inspections, the application of deep learning techniques is needed. However, for deep learning to be effective, a large amount of data is required. In order to address this need, the goal of this thesis is to derive, develop and implement a physics-based simulation model. It allows for the creation of new measurements with known defects, providing a large amount of data for training deep learning algorithms.

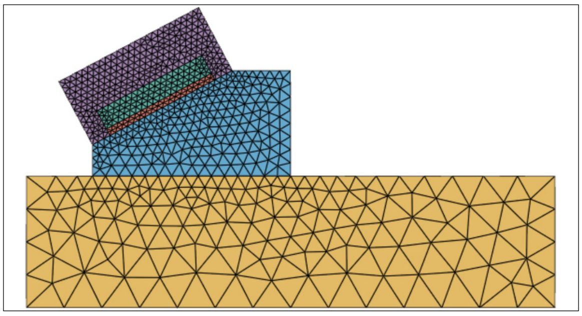
Approach: The proposed simulation model in this thesis aims to effectively generate data for deep learning algorithms. The simulation model is designed to be reasonably accurate by simulating the entire NDT process, from the input electrical signal to the output of the measured electrical signal, using the finite element method. The simulation process involves the accurate simulation of wave propagation in solids, the piezoelectric effect within transducers and the electrical circuits that are connected to the electrodes of piezoelectric transducers.This requires the derivation of mathematical models that accurately describe the system and the identification of suitable boundary conditions. To facilitate the simulation process, a domain creation software is also implemented.

Result: The thesis presents an in-depth examination of theories and models related to the finite element method and the development of a physics-based simulation model for ultrasonic nondestructive testing of welds. The proposed simulation model has shown promising results, particularly when applied to linear elastic materials. The research includes the implementation of a domain creation tool that can construct complex domains and automatically mesh them according to physical constraints. It also includes a software package that efficiently solves for 56870 degrees of freedom during 256 time steps in around 14.8 seconds on a single CPU.
However, further testing against real-world examples is needed to fully validate the accuracy and effectiveness of the simulation model.

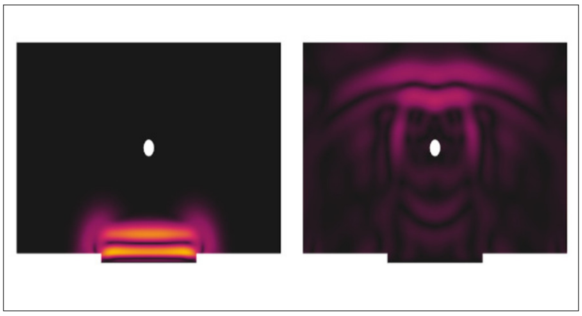
Software structure
Own presentment



Example of a created domain and automatic meshing
Own presentment



Displacement field at different time steps in a test block with a hole
Own presentment



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