Improvement of 3D-Active Thermography by using Artificial Intelligence

Johannes Rittmann, Marc Kreutzbruck

Institute for Polymer Technology (IKT); University of Stuttgart, Stuttgart, Germany

Abstract: For the one-dimensional case of heat propagation in active thermography the thickness of the investigated specimen can be directly reconstructed using known evaluation methods such as laser flash analysis or thermographic signal reconstruction and observation of a characteristic time. Concerning the multidimensional case diffusive effects have a strong impact on the heat propagation of the thermal wave, which leads to misinterpretations when evaluating the thickness especially at deep-lying edges and inhomogeneities in a specimen. The deeper a defect is located in the component, the more diffuse it is perceived in a change in surface temperature. Within this paper, heat flux simulations and real measurements of pulse thermography of different defect geometries are used to train a neural network for depth-resolved defect interpretation. The defect geometries are based on geometries of real impact damages in composites and were realistically obtained from a micromechanical fracture simulation. The neural network is based on an encoder-decoder approach where the temperature values of the cooling curve after a pulse-shaped excitation serve as input information. Segmentation is performed as a function of the backwall geometry. By training several thousand defect geometries using an encoder-decoder network, it was possible for the first time to directly infer the backwall geometry of a component without additional information about the component. Finally, it is shown how simulations can support the inversion of thermal waves for 3D-thermography of real measurements by an artificial intelligence system.

Keywords: thermography, artificial intelligence, three-dimensional prediction
Improvement of 3D-Active Thermography by using Artificial Intelligence

ECNDT, Lisbon
3. - 7. July 2023

M.Sc. Johannes Rittmann
Why do we use Artificial Intelligence?

Conventional NDT

Nondestructive Testing

Expert

Evaluation and defect detection

M.Sc. Johannes Rittmann
Why do we use Artificial Intelligence?
State of Science and Technology
Why do we use Artificial Intelligence?

Outlook

Rookie

Specimen

Evaluation and defect detection
Outline

- Motivation

- Data Generation

- Neural Network

- Results and Discussion

- Conclusion and Outlook
Experimental Set-up

Introduction Active Thermography

Specimen
Halogen lamp
IR-camera
Data Generation
Simulation of Impact Damages using FEM

Source: Bastek, Institut für Flugzeugbau der Universität Stuttgart
Data Generation
Representation of the Training samples

2500 impact samples

2000 non-impact samples
Puls excitation 0,5 s \( \text{Zeit} = 0 \text{ ms} \)
Data Generation

Data Flow in straightforward Problems

3D-Geometry:
Defect position and depth

Simulation or measurement

COMSOL or IR-camera

Video frames:
Amplitude and phase
(as function of position and time)
Solving Inverse Problems
Inverse data flow to determine the components condition

Video frames:
Amplitude and phase
(as function of position and time)

Neural Network

Unknown inverse function,
Black box approach

3D-Geometry:
Defect position and depth
Outline

- Motivation
- Data Generation
- Neural Network
- Results and Discussion
- Conclusion and Outlook
Neural Network

Full connected Neural Network

Input layer

Hidden layer

Output layer

I₁

H₁

O₁

I₂

H₂

W₁,₁

W₁,₂

W₂,₁

W₂,₂

W₁,₁

W₁,₂

W₂,₁

W₂,₂
Neural Network

Used Encoder – Decoder Net
Outline

- Motivation
- Data Generation
- Neural Network
- Results and Discussion
- Conclusion and Outlook
Results and Discussion
Prediction of Simulation data

Real state
Results and Discussion

Prediction of Simulation

Real state    AI-prediction    Difference

Real state    AI-prediction    Difference

Depth and difference in mm

M.Sc. Johannes Rittmann
Results and Discussion

Database and Measurements

- Training database of the NN consisting of 34 different samples
- Measurement time per sample 2 minutes → total measurement time < 2h
Results and Discussion
Prediction using Experimental Results

Real state
Results and Discussion
Prediction using Experimental Results

Real state | AI-prediction | Difference
---|---|---

Real state | AI-prediction | Difference

Depth and difference in mm

M.Sc. Johannes Rittmann
Can you see the dog on the roof?

- Even if only the dog’s head is visible?

- What would be the hit rate of an AI-System?

- Similar effects compared to human inspectors?
AI rule in der EU

Vorschlag für eine

VERORDNUNG DES EUROPÄISCHEN PARLAMENTS UND DES RATES
ZUR FESTLEGUNG HARMONISIERTER VORSCHRIFTEN FÜR KÜNSTLICHE INTELLIGENZ (GESETZ ÜBER KÜNSTLICHE INTELLIGENZ) UND ZUR ÄNDERUNG BESTIMMTER RECHTSakte der UNION

{SEC(2021) 167 final} - {SWD(2021) 84 final} - {SWD(2021) 85 final}
Outline

- Motivation
- Data Generation
- Neural Network
- Results and Discussion
- Conclusion and Outlook
Conclusion

- Neural Networks are versatile and very well suited for implementation in NDT applications.
- With good and consistent data sets, only a few data sets are needed for training an encoder-decoder network.
- Depth information of interfaces from noisy heat flow simulations can be determined with an average deviation of less than 0.1 mm.

Outlook

- Optimization of prediction of real measured data by training with simulation data.
- Extension of the NN to other defect types and materials.
- Transfer of the NN to other NDT applications and applications from plastics technology.
Acknowledgement

The shown research is part of a publicly funded project at Institut für Kunststofftechnik of the University of Stuttgart.

We acknowledge the Deutsche Forschungsgemeinschaft (DFG) for funding this project with funding number 470535306.
Improvement of 3D-Active Thermography by using Artificial Intelligence

ECNDT, Lisbon
3. - 7. July 2023

M.Sc. Johannes Rittmann