DeepWelds

Evaluation of Weld Seam Cross Section Images using Deep Learning

Graduate

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Introduction: The production of precision steel tubes for safety-critical automotive components requires highly precise welding processes to ensure the demanded product lifespan. At Mubea in Arbon, these tubes are manufactured from high-strength materials such as 34MnB5 and 26MnB5 using inductive welding. The quality of the weld seams is of utmost importance, as defects can lead to premature failure. Traditionally, the inspection of weld seams is carried out through time-consuming approval cuts, which require qualified laboratory personnel. This personnel staff is not always available in multi-shift operation.

Definition of Task: To simplify the approval process, this study investigates the feasibility of automating the detection of welding defects such as weld funnels and compression line collapse, as well as measuring the compression line angle using deep learning.

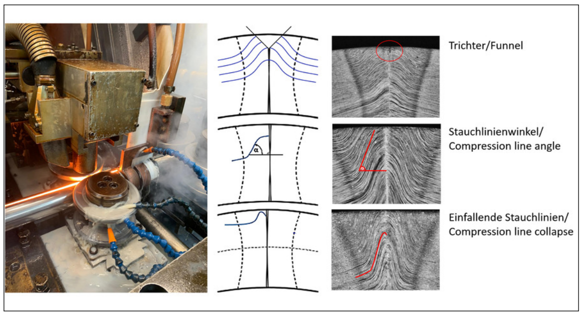
Result: Three different VGG-19 models were trained using supervised learning: two classification models for the detection of weld seam funnels and compression line collapse as well as a regression model for determining the compression line angles.

The first model is trained for detecting weld funnels. A pipeline was developed to automatically detect the ferrite line and the grind edge. This information is used to crop the image and load it into the model. The model achieved an F1 score of 0.7778 and a recall of 1.0. A recall of 1.0 was crucial because all weld craters need to be detected. Additionally, the interpretability of the model was examined using Grad-CAM to ensure that the weld crater area is indeed being evaluated.

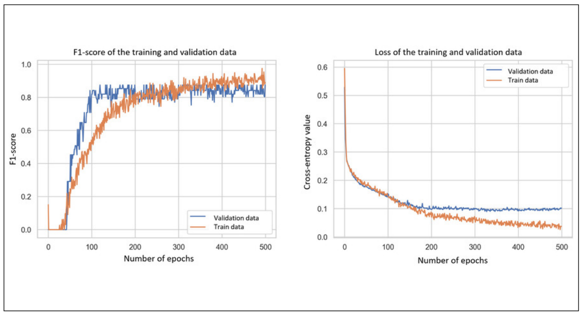
The second model is a regression model for determining compression angles. The results showed that the model has a narrower 99.7% confidence interval of -4.2° to 4.1° compared to manual measurements (-6.4° to 6.7°). The test dataset demonstrated that the model's variance is half that of the manual measurement of compression angles using Keyence software.

The third model is used for identifying collapse of the compression lines in the critical area. A pipeline was employed that automatically detects the ferrite lines and edges to appropriately crop the image. The model achieved an F1 score of 0.875 and a recall of 1.0, confirming the reliable detection of all collapse compression lines in the critical area. The interpretability of this model was also examined using Grad-CAM.

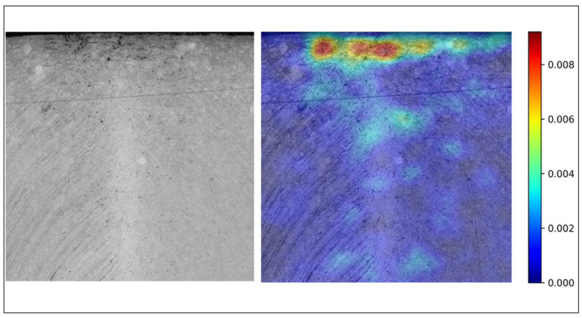
Welding process including weld seam characteristics
Herberhold, D.: Schematic representation of weld defects



Learning and validation curves of the weld funnel training
Own presentment



Grad-CAM weld funnel classification. The model is able to capture the relevant regions in the cross section.
Own presentment



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