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SIMULATION OF AN INSTRUMENTED ULTRASONIC TEST RUN WITH A RAIL INSPECTION TRAIN

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ABSTRACT

Rail inspection performed by ultrasonic rail inspection trains is a complex and challenging process. A large number of variables and parameters given by the environment, the track and the testing-system have an influence on the overall performance of the inspection and the inspection result. Typically the parameter vary in a combination depending on the track condition.

To evaluate the individual influence of each relevant variable, simulation tools can be used. Therefore the entire inspection process has to be transferred into a model using combined modelling techniques.

The goal of this work is to model an instrumented ultrasonic test run with a rail inspection train with the parameters varied by a script over a virtual driven distance.

Keywords: ultrasound, rail inspection, modelling, simulation

1. INTRODUCTION

Ultrasonic rail inspection poses strong challenges to the process itself to receive reliable inspection results independent of track type and wear. Large amounts of data have to be collected in a short period of time searching for complex flaw types under constant changing conditions. Rail type and wear may vary over the inspected section of track in an irregular sequence, e.g. switches, curves, bridges and crossings, while environmental conditions and inspection speed may also vary.in parallel.

The essentially influencing parameters on the performance of the inspection have to be evaluated. This makes it possible to understand the detailed behavior of the system for the operator himself to adjust proper settings as well as for the estimation of the probability of detection as well as for the design of signal processing algorithms for automated indication classification.

To conceive the dependencies of each individual influencing parameter on the inspection results the whole process has to be analyzed and modelled in detail. For this work simulation results, laboratory scale measurements and field test have to be considered, evaluated and brought together.

For validation the standard DIN EN 16729-1 [1] formulates reference flaws which can be used for the lab, the field and the simulation.

2. METHODS

The rail inspection system presented in [2] with 70°, 55° and 35° angle beam 2 MHz probes and two different 0° straight beam 4 MHz probes has been used as a basis for this investigation. The main signal processing algorithms and its parameter setups have been modelled using Python and the NumPy library. For the display of measured and virtual inspection results the display format of the “Glassy-Rail-Diagram” (GRD) [3] has been used.

2.1 Test rail

For laboratory tests a test rail made from a 1 m segment of a UIC 60 rail has been manufactured. It incorporates seven side drilled holes in different depth with diameters from 5 mm to 33 mm in the rail web, 4 sickle shaped notches on the running surface and the rail foot and 6 flat bottom holes in the rail web and foot.

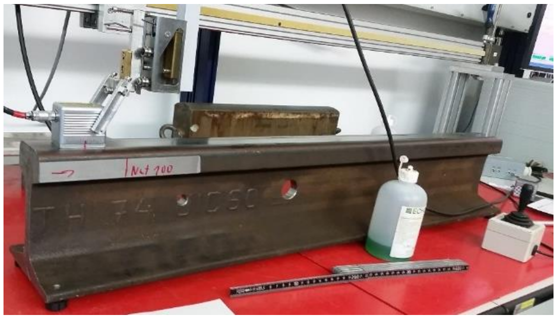

FIGURE 1: UIC 60 TEST RAIL WITH 35° PROBE

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The running surface has been machined flat in the region of the rail web to avoid jitter by coupling during reference measurements.Figure 1 shows the test rail during mechanized lab scale measurements with a 35° probe.

2.2 Simulation

Different 2D and 3D simulation tools have been used to model the ultrasonic response of the rail geometry itself and the artificial geometries (e.g. different types of flaws, drillings, weldings). Semi-analytic models have been implemented using CIVA software. Finite element models have been implemented using ANSYS software. For each probe-reflector-geometry at least one model has been build.

As an amplitude reference for all simulations a drilling in the middle of the web with a diameter of 33 mm has been used. This type of drilling is a feature of fish plate junctions which can be found in rails all over the world. This makes the simulation results comparable to lab scale measurements and inspection data from the field. Additionally it offers the mixture of simulated an measured data aligned on a reference amplitude.

For the modulation of the variable parameters Python scripts have been developed. When assembling a virtual track from simulated data, parameters can be varied for each simulated segment.

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2.3 Field data

For the investigations on field measurements an anonymized data set has been used. This data set has been consulted for the comparison of indications derived by real rail artefacts. Additionally the structure of noise and spurious signals have been extracted to generate synthetic parasitic signals to be added to the simulation with variable amount.

2.4 Influencing Parameters

As the main relevant influencing parameters the following have been identified during the project work:

- rail geometry
- probe position offset
- coupling conditions
- inspection train speed
- probe parameters
- parameters of ultrasonic system
- parameters of data acquisition
- noise and spurious signals
- flaw type and flaw geometry

3. RESULTS

Virtual rail inspections have been carried out using Python scripts with varying parameters using the prior simulated data. A typical data set can hold data up to 1000 m rail with a resolution of 3 mm by 3 mm. Data are typically displayed in GRD-format in section with a width of 1 m [3,4]. The upper image shows the reconstructed maximum amplitude data of all probes color coded in rainbow color scheme. The lower image indicates the gate data with the probe type color coded. For the following two examples an inspection speed of about 60 km/h has been simulated.

An example result from the virtual inspection is given in Figure 2. It shows the indications of two different drillings with 33 mm and 16 mm diameter. The indication from the rail foot is displayed at the bottom (172 mm). Additional indications in the web derived from mode converted wave fronts from the rail head to rail web transition can be found in the amplitude data only (these signals are below the gate threshold). Additional noise with an amount of 2% has been added in this section.

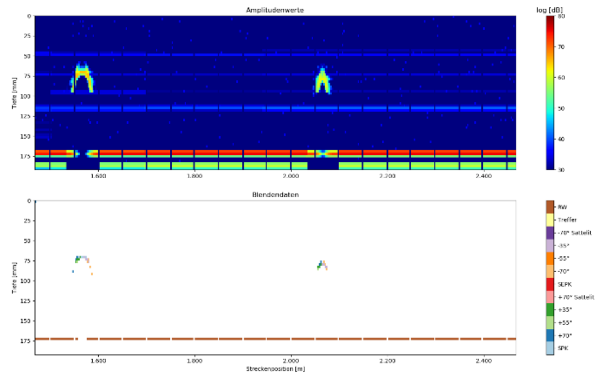

FIGURE 2: VIRTUAL INDICATIONS FROM TWO DRILLINGS IN THE RAIL WEB

In Figure 3 a virtual inspection result from a flaw close below the running surface is shown. The shape of this flaw represents a typical rail defect of the type SQUAT. The simulated lateral length of the flaw is 50 mm.

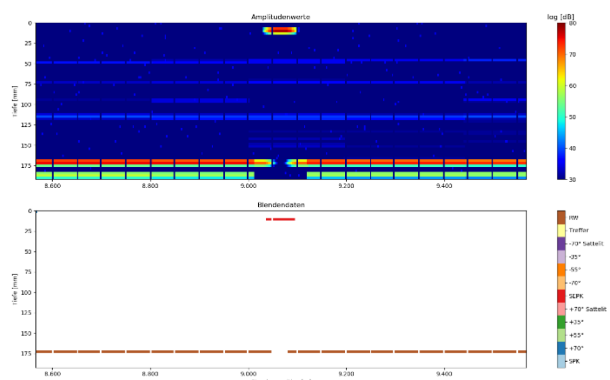

FIGURE 3: VIRTUAL INDICATION FROM A SIMULATED SQUAT-TYPE RAIL DEFECT

The indication from the rail foot is displayed at the bottom (172 mm). There is a significant loss of backwall echo present in the area of the flaw. Again additional indications with low amplitudes in the web derived from mode converted wave fronts from the rail head to rail web transition can be seen. A certain amount of noise has been

To give a comparison of virtual rail inspection against data measured in the field, Figure 4 shows the indications of two drillings and a weld in between with no defect present. The noise level in this measurement is quite high and spurios signals from the transition from weld to rail material are present.

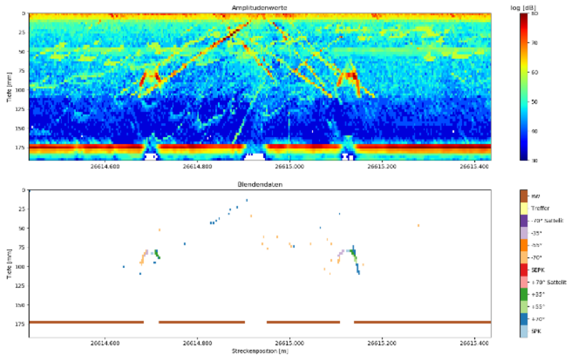

FIGURE 4: EXAMPLE DATA SET TAKEN FROM MEASURED DATA IN THE FIELD

4. CONCLUSION

Mechanized rail inspection is a complex process. To evaluate the influencing parameters on the process, simulation tools can be used. In this work a script based simulation tool based on semi-analytic and FEM has been developed. The whole acoustic and electric signal chain has been represented in the simulation using Python and the NumPy library. The relevant influencing parameters have been identified and can be modified for each section while synthesizing a virtual inspection. Example virtual inspection results will be presented. This work helps to understand the influencing processes on the overall inspection performance of rail inspection trains and will unclose the possibility to establish validated signal processing algorithms for automated classification of rail defects.

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