Academic Education in NDT at Master Level and Resulting Implications on the NDT Community

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NDT is a science based between different disciplines (applied physics, applied mathematics, computer science, electronics, material science and engineering structural design).

Organisations struggling to find personnel adequately trained in NDT

Provide academic teaching in NDT at highest level.

Highly educated graduates in NDT will shorten the lead time in getting graduates effectively hosted in an NDT working environment.

Bologna process allows for:
  • an interesting mix between a natural science subject (bachelor) and NDT (master)
  • life long learning.
Why an M.Sc. Course in NDT at DIU?

• Conventional universities have difficulties in providing the breadth of teaching staff required (i.e. academic and departmental autonomies)
• DIU can easily hire excellent staff from virtually anywhere on a time limited basis
• Staff appointed must have the adequate proficiency in English language skills
• Courses can be configured in accordance to any needs
• Short decision processes due to simple organisational structure
• NDT Master Course accredited by Saxonian Ministry of Science & Culture and ZeVA
M.Sc. Program „Non-Destructive Testing“: Network

• For this study program, DIU is the leading institution in the network consisting of:
  • Dresden University of Technology
  • Universität des Saarlandes, Saarbrücken
  • Fraunhofer Gesellschaft
  • German Society of Non-Destructive Testing (DGZfP), Berlin
  • Bundesanstalt für Materialforschung und –prüfung (BAM)
  • ... and more to come.

• Students will be familiarized with modern equipment based on all major methods in NDT

• The program is tailored towards an advanced specialization in mechanical, electrical and civil engineering and can lead to highly promising professional careers.
• Completed in a consecutive sequence.

• Laboratory sessions within the research modules are carried out in the research labs of academia, BAM, Fraunhofer, and industries.

• The concept covers 5 basic modules, 5 specialized modules, 1 certification module and 2 modules related to own research including the Master Thesis.

• Furthermore, each student can apply for a special certificate of the German Society of Non-Destructive Testing (DGZfP).
Modules and Lectures

1 Basic Modules (BM): Material Science (Metals; Polymers); Measurement Techniques; Mechanics (Sound & Vibration; Fatigue & Fracture); Numerical Methods & Signal Processing; Introduction into NDT and Quality Management.

2 Specific Modules (SM): Acoustic Methods (Ultrasonics, Phased Array & Imaging); Electromagnetic Methods (Electromagnetics, NMR, Eddy Current, Microwave); Radiology (Fundamentals, Tomography, Imaging); Optical Methods; Thermal & Microscopical Methods

3 Specific Actions (SA): NDT Basic Course of DGZfP (a Gateway to Certified Testing); Research Internship at BAM, Fraunhofer, or others

4 Master Thesis (MT): Performed with one of the Academic Institutions, BAM, Fraunhofer, or others
Reknown Lecturers in their Fields

- Dr. Carsten Becker-Willinger, Leibniz INM (Polymer Materials) Saarbrücken/Germany
- Prof. Dr. Christian Boller, Saarland Univ. LZfPQ & Fraunhofer IZFP, Saarbrücken/Germany (Mechanics)
- Prof. Dr. Gerd Dobmann, Saarland Univ. LZfPQ Saarbrücken/Germany (NDT Introduction; Electromagnetism)
- Prof. Dr. Uwe Ewert, BAM, Berlin/Germany (Radiography Imaging)
- Prof. Philippe Guy, INSA, Lyon/France (Acoustic Methods)
- Dr. Wolfgang Habel, BAM, Berlin/Germany (Optics)
- Dirk Henn, Fraunhofer IZFP, Saarbrücken/Germany (Quality Management)
- Prof. Dr. Johann Hinen, FH Stendal, Stendal/Germany (Microwave & Eddy Current)
- Dr. Ralf Holstein, DGZfP, Berlin/Germany (NDT Course for Basic Qualification)
- Dr. Yan Kai, SWJTU, Chengdu/China (Optoelectronics)
- Dr. Andrzej Klepka, AGH, Cracow/Poland (Numerical Methods & Signal Processing)
- Dr. Andreas Kupsch, BAM, Berlin/Germany (Radiographic Methods)
- Dr. Fabien Léonard, BAM, Berlin/Germany (Radiographic Methods)
- Dr. Peter Starke, Saarland Univ. LZfPQ, Saarbrücken/Germany (Metallic Materials)
- Prof. Dr. Wieslaw Staszewski, AGH, Cracow/Poland (Numerical Methods & Signal Processing)
- Prof. Tadeusz Stepinski, AGH Cracow/Poland (Acoustic Imaging)
- Prof. Dr. Volkert Trappe, BAM, Berlin/Germany (Composite Materials)
- Prof. Dr. Frank Walther, TU Dortmund, WPT, Dortmund/Germany (Measurement Techniques)
- Dr. Mathias Ziegler, BAM, Berlin/Germany (Thermography)
- Prof. Dr. Ehrenfried Zschech, Fraunhofer IKTS, Dresden/Germany (Microscopy)
- Dr. Uwe Zscherpel, BAM, Berlin/Germany (Radiographic Tomography)
DGZfP Basic Course in NDT

- DGZfP is the German Society for NDT, the world’s oldest NDT society
- DGZfP Basic Course (BC):
  - Is an accredited course
  - Lasts 10 full days
  - Provides a practical and theoretical background into all relevant NDT techniques
  - Allows to directly go for DGZfP Level III certification in the different NDT techniques addressed after relevant experience with the NDT technique
  - Is run at DGZfP headquarters in Berlin/Germany
First Batch of Graduates in November 2015

7 of 12 graduates secured PhD position
Ting Wang: Characterization of the Interfaces of Ballastless Railway Tracks Based on Ultrasonic Echo Principles
Ballastless Track & Potential Damages
Ultrasonic Inspection Equipment

Image of tomograph A1040 MIRA

Low-frequency ultrasonic flaw detector A1220 MONOLITH
Elaboration on a Real Ballastless Track Section

For various ballastless track systems of Deutsche Bahn (DB), relevant ultrasonic methods have been investigated in joint research projects of DB and BAM around the year 2000. Fundamental knowledge of inspecting different ballastless track systems has been obtained as well as forecasts and necessary boundary conditions for a possible application in practice could be derived which has been published \[27\]. An implementation of those ultrasonic methods in practice has however not become known so far.

4.1 Experiment

A real Boegl system ballastless track at BAM has been provided by Deutsche Bahn (DB) in the year 2000 and is shown in Figure 4-1. The ultrasonic tomograph A1040 MIRA device was chosen to measure the Boegl system. The sketch and cross section of the system are shown on Figure 4-2.

The measurements were carried out in 3 measuring grids with a 5 cm step distance. The measuring grid of each one is shown in Figure 4-3. The grids from up to down shown in Figure 4-3 are named Boegl_1, Boegl_2 and Boegl_3 respectively. For Boegl_1, there are 11 x 8 measuring points, 11 horizontal lines and 8 vertical lines. For Boegl_2 and Boegl_3, there are 10 x 8 measuring points due to the fill hole, 10 horizontal lines and 8 vertical lines.

In the MIRA inspection system, three maps being the same in terms of the measuring grids have been pre-established with pre-settings. The ultrasonic frequency is 50 kHz, the offset is 20 μs and the velocity is 2700 m/s.
Concrete/Polyamid/Concrete with Defects

Simulation of shear waves:

Simulation: K. Mayer, Univ. Kassel/Germany

B-scan

C-scan
Su Chen: POD Analysis for Single Rebar in Concrete Using Ultrasonic Echo Method
3D SAFT Image Processing for Rebar Detection

Data Processing: K. Mayer, Univ. Kassel/Germany
Yevgeniya Lugovtsova: Condition Monitoring of Wooden Poles Using Guided Waves
Signal Processing Approach

System Transfer Function: \[ I(\omega) = \frac{X(\omega)}{S(\omega)} \]

\( X(\omega) \)  Spectrum recorded
\( S(\omega) \)  Spectrum actuated

Tichonov’s convolution regularisation:

\[ I(\omega) = \frac{S(\omega)^* \cdot X(\omega)}{(S(\omega)^* \cdot S(\omega) + \varepsilon) \cdot dt} \]

\( \varepsilon \)  Regularisation factor
\( dt \)  Time interval
\( S(\omega)^* \)  Complex conjugate of spectrum

Impulse response function (IRF):

\[ i(t) = FFT^{-1}(I(\omega)) \]
MOVERS OF TOMORROW

„During my master studies at Tomsk Polytechnic University I happened to know about the university’s cooperation with DIU. This allowed me to participate in the “non-destructive testing” course in Dresden. Besides the additional degree this study provided me international experience and I happened to know the German education system. What I felt very positive with DIU was that many lecturers made their longstanding professional experience to become a part of their lectures. After my subsequent research placement at the ‘Federal Institution of Materials Research and Testing’ in Berlin I was also allowed to write my master thesis there and I am now working towards my doctoral degree.”

Yevgeniya Lugovtsova, PhD Applicant
Yevgeniya Lugovtsova: Structural Health Monitoring of Composite Pressure Vessels using Guided Ultrasonic Waves

Finite Element Modelling

Propagating modes

Reflection from a 1 mm crack in the aluminium liner

Out-of-plane excitation between metal and CFRP plates

In-plane component

Out-of-plane component

In-plane GW in liner

Out of plane GW in composite & liner

Fibre reinforced plastics overwrap

Aluminium liner

MCS International GmbH

BAM
Jianguang Guo: Induction Thermography of Carbon Fibre Reinforced Plastics

Amplitude

Phase
Viktor Lyamkin: Correlation of Residual Stress Measurements by Neutron Diffraction and Metal Magnetic Memory Testing in Ferritic Steel Welds
Viktor Lyamkin: Life cycle estimation of metallic components in nuclear industry based on non-destructive detection and interpretation of local material properties
Ruth de Acosta: Defect Detection During Laser Welding by Laser Speckle Photometry

Figure 4.3. Laser MPNG welding experiment set-up and LSP setup.

4.3.1 Hardware adaption and settings

Excitation of the sample

The LSP measurements were taken continuously during the welding process, therefore, the heat of the welding process was used as thermal excitation source. The Laser Power used for both samples ranges between 1 and 4 KW, with a heat input between 1.2 and 4.8 KJ/cm, reaching temperatures inside the weld seam up to 90–110°C measured at the last layer surface.

Speckles excitation

Two laser sources in two different positions were used to illuminate the sample and excite the speckles pattern. The first position on the top of the specimen is an 808 nm wavelength laser diode and in the second position at 90 degrees, a 450 nm laser diode was used for the sample SN_17 and for the first layers of sample SN_18; for the last layers of this sample a 532 nm diode was used. The experimental setups are detailed in Figure 4.3 and Table 4.2 at the end of this section.

As presented in Figures 5.9 and 5.10, layer 2 was welded the first day, which layers were good quality, with few defects. Also, from these pictures, it can be seen that good layers are present in sample SN_018 on day 5, which corresponds to layers 69 to 92. Results of the LSP analysis for layer 83 are presented in Figure 5.12, where no defects can be detected.

On the other hand, on layers 29 to 69 a lot of lack of fusion were formed. This is presented in Figure 5.13 for layer 39, which had lack of fusion on both sides of the weld seam. It can be seen in the second picture of Figure 5.13 that the possible areas which correspond to lack of side wall fusion are detected. If the second picture of Figure 5.13 is compared with the second picture of Figures 5.11 and 5.12, it is noticeable that higher indications occur in Figure 5.13. Moreover, in the third picture, high amplitudes occur before and after or around the detected dark areas, which can be related to the presence of defects in both sides of the weld seam.
Ruth de Acosta: The Use of NDT for Microstructure Based Residual Fatigue Life Assessment of Metallic Components
Benefits for Collaborating Organisations

• Provide graduates with a knowledge and experience in NDT better than conventional graduates
  • Shorter lead time to become an NDT expert
  • Qualifies directly to a level III after the respective experience
• Allow for a master degree even after years of professional life (life long learning)
• Combine research placement and master thesis with research related topics of the collaborating organisation
• Explore ideas that would not be possible to be explored within the collaborating organisation
• Establish links with renowned academic institutions
Conclusions

- Nearly five years of experience show the course to be feasible, sound, realistic and value added
- Hard work to get the course established
- Appearance has increased with an increasing number of students and partners from academia, research organisations and industry
- Provide a platform of highest academic level in NDT education and research as well as intercultural exchange.
Contact
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