



International Academic Education in NDT at Master Level

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Abstract. Non-destructive testing (NDT) has been widely recognised as an own field of science and technology covering a very broad range of applications. This starts from applied physics and is going its way through all disciplines of engineering and even encompassing applied mathematics as well as computer science those days. This broad field and the need for NDT experts not just at technical but also at academic level has been the motivation for establishing a postgraduate master course in NDT. Dresden International University (DIU), which is Dresden Technical University's university of advanced training has been a most suitable institution to get this idea of an NDT master course established. The flexibility in organising courses at DIU due to its status of being a private university has allowed an NDT master course to be established with renowned lecturers for the different modules required, recruited from different places in the world. This has allowed a course of excellence to be established, run now since 2013. The course is organised in four semesters and has a strong scientific and hence research focus. In the first semester students are taught in all the major fundamental disciplines such as metallic and polymer materials, measurement techniques, sound & vibration, signal processing, optics, electromagnetism and quality management. In the second semester major emphasis is on the different NDT techniques including acoustics, optics, electromagnetism, radiology and microscopy. The third semester is devoted to participating in the Basic Course of the German Society for NDT (DGZfP) and a research placement in reputable research centres such as the affiliations of the different lecturers including BAM in Berlin, Fraunhofer or different universities with a specific dedication to NDT. During the fourth and final semester students do perform their master thesis, most likely with the institutions they already performed their research placement with. The course is fully taught in English with modules run consecutively as a block. Location of teaching is mainly in Dresden/Germany. The course is also offered and further developed as a double degree (DD) course between DIU and another university abroad where the first and the last semester is taken at the sending university while the two middle semesters are taken at DIU.

1. Motivation

Non-destructive testing (NDT) is increasingly gaining importance to sustain quality with either new or existing products and infrastructure. This is not just limited to the highly industrialised societies but rather also to those emerging in terms of technology, industrialisation and economy. NDT has therefore become an essential need on a fully international basis. NDT is not just an agglomeration of techniques to be applied but rather a science to be based between the classical disciplines of applied physics, applied mathematics, computer science, electronics, materials science and engineering structural design. Significant scientific and technological development in all of those disciplines gives rise to also consider this within the context of NDT. Leaving this technological development solely to



what is happening in the classical disciplines of computer science, mathematics, physics or the different engineering disciplines (i.e. civil, electrical, materials, mechanical) will not sufficiently address the needs of NDT itself but rather to those of the classical disciplines only, which may likely limit the applicability of a NDT technique being developed.

A major motivation for establishing a master course in NDT has been to provide academic teaching of NDT at highest level and to educate and train people that are able to take over a responsible and hence leading function in either discipline and profession being directly or indirectly associated with NDT. In that regard specifically the area of NDT science and technology is addressed where many of the R&D institutions are struggling to find adequately trained personnel, which traditionally has to be recruited from neighbouring disciplines otherwise and has then to be adequately trained until it can productively work in the NDT research field addressed. This is definitely time consuming and costly and is underlining the general say that NDT training is a matter of years if not even decades.

The generalised application of the Bologna process within academic education specifically now in Europe where academic education is split between a bachelor and a master degree specially allows for a suitable combination in a way that a fundamental classical subject such as computer science, engineering, mathematics or physics is studied for a bachelor degree and is then followed by a master degree in NDT. This allows for the fundamentals of a specific science to be laid during the bachelor studies followed by the more specialised studies along a NDT master course.

A further flavour with the Bologna process has to be seen with the fact that an academic course can be virtually taken at any step in life as long as the requirements for registration are met. Students may therefore have taken a job after graduating with a bachelor degree first before deciding to go for a master degree after a few years. This has generated much more mature students at a master level because the decision to take the course has been founded on practical experience within the profession and mostly fully by the student him- or herself rather than from a societal environment. Principally this has made the idea of lifelong learning more realistic.

There are not too many academic courses offered in NDT so far. The reason is that the NDT chairs are usually spread over different academic institutions and the minimum critical mass of academic personnel representing the different essential disciplines required may not be present at a single academic institution. Furthermore it may still be difficult to fill a complete course with an adequate number of students and this specifically within a country where English is not the general language applied for teaching. NDT so far taught as a discipline has more been within the field of certified training where engineering colleges have taken NDT as a subject towards accredited training. NDT in view of true academic discipline including education, advanced training and research is still a novelty and challenge, which is gaining increased attention and importance in the longer term.

Dresden International University (DIU) is a new type of a privatised German university that serves as an advanced training university spun out of Dresden Technical University. It allows special courses to be configured in a fairly uncomplicated way such that a course can be configured with lecturers to be recruited from virtually any part of the world as long as the business concept matches the tuition fee income versus the expenses being generated. Before appointing lecturers the course has however to be configured and accredited at least by the Saxonian Ministry of Science and Culture (SMWK). Once accredited the launching date of the course only depends on the availability of the respective lecturers. Teaching can

be done either along the premises of DIU at Dresden or virtually at any other location would that be more suitable from a strategic point of view.

Courses at DIU can either be run in German or in English. Besides the availability of a broader selection of lecturers the flavour of running a course in English has to be seen in the possibility of running a course also in the form of a double degree (DD). In that case a partner university is required in another country, which is able to run an adequate portion of the course at its own institution in English and where the course needs to be accredited as well.

How this all has been realised in the case of an NDT master course is explained in the following chapters below.

2. Prerequisites

The NDT Master Course at DIU taught in English was established in 2013. The idea to establish this course as a double degree was originally generated along discussions with different universities in China, India and Russia. In all of those countries – and certainly in others too – there is a belief that the enhanced requirements in industrialisation will result in an increased need for quality assurance and hence for NDT including the respective technologies and also research. Euphoric numbers of potential students quickly brought figures to reality in a way that:

- Awareness of NDT in the general public is still less than the NDT community believes it to be;
- Modules to be taught at the partner universities were partially not at a level adequate to the requirements set at DIU;
- Some of the staff's proficiency in English language was insufficient in terms of meeting the standards set;
- DIU tuition fees (although comparatively low when compared to others) were still too high for some of the partner universities.

These restrictions led to the idea to also offer a so called single degree (SD) course, along which all the modules are taught at DIU in Dresden for the duration of two years. This option has allowed to also teach some of the modules on behalf of the partner university along the DD course by DIU hired staff until the partner university has achieved a level at which it is able to provide the module itself. Furthermore there are an increasing number of students who apply for the single degree straight away, mainly because they could not be registered with a partner university or did not graduate from this.

Students applying for the course must have at least a bachelor degree or higher in an engineering or natural science discipline with acceptable marks awarded from an accredited academic institution. The student must further prove his/her English language proficiency through an accredited test and meeting a threshold (i.e. IELTS 6.0, TOEFL iBT 79) added by an oral interview and a written test as part of the admission of the course.

3. Structure of the Course

The course is a 120 ECTS credited course divided into four semesters. In its current configuration it consists of 21 modules including the master thesis ranging between 3 and 30 ECTS credit points each. The different modules being taught include:

Basic Modules (BM) (Semester 1): Metallic Materials; Polymer Materials; Measurement Techniques; Quality Management; Numerical Methods & Signal Processing; Electromagnetic Field Theory; Sound & Vibration; Optics

Specific Modules (SM) (Semester 2): Acoustic Methods (Ultrasonics, Phased Array & Imaging); Electromagnetic Methods (Electromagnetics, NMR, Eddy Current, Microwave); Radiology (Fundamentals, Tomography, Imaging); Optoelectronics; Thermography; Fatigue & Fracture; Microscopy.

Specific Actions (SA) (Semester 3): NDT Basic Course of DGZfP; Research Internship

Master Thesis (MT) (Semester 4): Performed at a research institution or possibly with an industrial partner.

An overview of the modules including the different ECTS credits awarded is shown in Table 1 below.

Module	Sem. 1	Sem. 2	Sem. 3	Sem. 4
Basics:				
- Material Science				
o Metallic Materials (BM-1.1)	3 CP			
o Polymer Materials (BM-1.2)	3 CP			
- Measurement techniques (BM-1.3)	3 CP			
- Quality Management (BM-1.4)	3 CP			
- Numerical Methods & Signal Processing				
o Lecture & Exam (BM-1.5)	3 CP			
o Lab Sessions marked (BM-1.6)	3 CP			
- Electro-magnetic field theory (BM-1.7)	3 CP			
- Sound and Vibration (BM-1.8)	3 CP			
- Optics (BM-1.9)	3 CP			
- Introduction to NDT (BM-1.10)	3 CP			
Acoustic methods				
- Ultrasonics (SM-2.1)		3 CP		
- Phased Array & Imaging (SM-2.2)		3 CP		
Electro-magnetic methods				
- Electromagnetics & NMR (SM-2.3)		3 CP		
- Eddy Current Testing (SM-2.4)		3 CP		
Radiology				
- Radiology Basics (SM-2.5)		3 CP		
- Tomography & Imaging (SM-2.6)		3 CP		
Thermography (SM-2.7)		3 CP		
Optoelectronics (SM-2.8)		3 CP		
Microscopic Methods (SM-2.9)		3 CP		
Fatigue, Fracture & NDT (SM-2.10)		3 CP		
BC-Course of DGZfP (SA-3.1)			15 CP	
Research Internship (SA-3.2)			15 CP	
Master thesis (MT-4.1)				30 CP
ECTS	30 CP	30 CP	30 CP	30 CP

Table 1 Structure of NDT master course including ECTS credits awarded

All modules are taught in a block lasting usually two weeks minimum to also allow for adequate time of self-study. All lectures are fully taught in English and the lecturers have

been well selected from various places in Germany, Europe and partially also overseas. Students do assess the teaching providing a feedback to the lecturers in terms of quality assurance. Lectures do include classical interactive teaching as well as exercises and partially also practical work. The latter is specifically mandatory within the Measurement Techniques (BM-1.3) and Numerical Methods & Signal Processing (BM-1.6) module.

The Basic Course of DGZfP (SA-3.1) is an accredited course run by the German Society for NDT (DGZfP). This course allows the student to directly apply for a DGZfP level III certification in a specific NDT technique once the respective experience has been gathered without having to apply for any intermediate level. Students attend this course at the DGZfP headquarters in Berlin/Germany, where they get fully exposed to the different NDT techniques addressed from a practical point of view.

The research placement takes mainly place at an academic institution or a research establishment where the Federal Institute for Materials Research and Testing (BAM) and Fraunhofer as well as Saarland University have been the key players so far. Recently also a small enterprise (FIT in Magdeburg) provided a placement. Discussions are held with further institutions and organisations in that regard. Principally any organisation is welcome to provide a research placement provided the topic addressed has the adequate R&D relevance. This relevance can be checked with the scientific management of the NDT master course beforehand.

The master thesis can be run at a R&D establishment or a university, depending on the issuing institution and the supervising DIU member of staff. It is often combined with the research placement, which gives the student a total period of around 8 months to deal with a research subject. The research subject for the research placement either/or master thesis is initially defined by the hosting institution and is well agreed upon by the supervising academic staff from DIU. In many cases DIU staff hosts a student at its institution, which makes the process fairly less complex. Students therefore do move away from Dresden for that period to the location of their hosting institution and will only come back to Dresden for the defence of their thesis.

In case of the double degree (DD) the regulations of the partner university apply as well. Principally the master thesis is performed with the partner institution. However, if circumstances allow the master thesis may also be performed in Germany at DIU with the consent of the partner university or as a joint thesis between DIU and the partner university.

4. Experience gathered

The course started in October 2015 for the third time and the first cohort of students who started in 2013 have mainly graduated. Topics covered along the different master theses included the following:

- Crack detection on ceramics based on the method of laser speckle photometry
- Probability of detection of single rebars in concrete structures using the ultrasonic impulse-echo method
- Non-destructive characterization of electrochemical deposition of calcium-phosphate coatings on nanodiamond modified titanium based implant material and study of their dissolution behaviour using a micro fluid system under simulated body fluid
- Computation and correction of X-ray refraction effects in phase contrast radiology
- Combination of X-ray tomography and in-situ micro mechanical testing of composites

- Condition monitoring of wooden poles based on wave propagation and vibration analysis
- Correlation of residual stress measurements by neutron diffraction and metal magnetic memory testing in ferritic steel welds
- 3D microstructure characterization and residual stress analysis of Al-MMC
- Thin RF magnetron sputtered hydroxyapatite + zinc coating investigation
- Simulation of inspection tracks for optimum robotic ultrasonic inspection
- Characterisation of the interface of ballastless railway tracks based on ultrasonic echo principles
- Characterization of high-strength ceramics using correlative analysis of laser-acoustically measured data.

Theses were performed at BAM in Berlin/Germany, Fraunhofer IKTS in Dresden/Germany, Saarland University (LZfPQ) in Saarbrücken/Germany, Southwest Jiatong University in Chengdu/China and Tomsk Polytechnic University in Tomsk/Russia. A major requirement of each of the theses was that they meet clear research challenges. An additional desire has been that one or two publications, mainly in the form of conference papers, could be retrieved from the research performed. Although this desire could possibly not be met in all the cases, it has generally generated a high standard of scientific output from the theses, which has motivated different institutions to offer the graduates a position for a follow-on doctoral degree. Seven of the twelve candidates due to graduate in 2016 have already received offers for a follow-on doctoral degree, which is an extremely high percentage demonstrating the scientific value of the work having been done. However, this is also a major intention of the course delivering top class students allowing to tackle challenging NDT issues to be solved and taking over a leadership on how to implement NDT into engineering and society best.

A very essential prerequisite for a student's success in the course is good proficiency in English. Principally students are making further good progress in their English skills during the course which is generally observed when they are due to present various of their achievements specifically during the third and fourth semester. In case of lacking English language skills students may also be sent to some additional English class out of hours or recommended to attend some 'debating clubs' where they will be encouraged to practise and enhance their English language skills.

Recruitment of students has so far still been a difficult process. However, the numbers of students are slightly increasing specifically after some focused marketing measures having been started recently. Generally the need for NDT-related academic graduates has still not been sufficiently recognised within the global community and societies as such. However, with increasing quality standards worldwide and an increasing amount of ageing infrastructure on the other hand a market will rapidly grow that will need people with a deeper understanding on how to assess the conditions and quality of those different products and infrastructure being at stake. It is specifically from emerging countries such as China, India, other South East Asian countries or Latin America where the number of applications have been increasing.

Another important point often discussed is tuition fees. Those are currently set at 4,500 € per semester and include all teaching material as well as participation in the Basic Course of the German Society for Non-Destructive Testing (DGZfP) in the 3rd semester. It should also be kept in mind that tuition fees are an obligation for the teaching staff to make the best out of a student's capabilities. This is provided by small student classes, being current-

ly in the range of 12 to 15 students and are not due to exceed 30 students per class. It is further added by ‘clinics’ or other means of training where students may be additionally trained with respect to meeting the specific targets of a module. DIU also provides a service to find suitable student accommodation as well as getting familiarised with German registration systems, insurance and different other administrative affairs.

The double degree (DD) option is a speciality of the NDT master course. In that case the degree is awarded by DIU and a partnering institution where the partnering institution is providing the lectures in the 1st semester and is supervising the master thesis in the 4th semester while the modules in the 2nd and 3rd semester are provided through and held mainly at DIU. Currently the DD option is performed jointly with Southwest Jiatong University (SWJTU) in Chengdu/China with success. Although SWJTU is currently not in a position to deliver all modules requested in English in the 1st semester a scheme has been developed that students can attend those modules at DIU along its single degree (SD) course. Partially DIU lecturers have also been invited to teach at SWJTU in Chengdu/China and vice versa, which has generated another interesting exchange of teaching staff between the two academic institutions. To get such a DD scheme running an accreditation of the course is required from each side of the partnering institutions. In the case of DIU this has been achieved through the Saxonian Ministry of Science and Culture (SMWK) while in the case of SWJTU it has been achieved through the Chinese Ministry of Education (MoE).

5. Future Plans

The English taught NDT Master Course at DIU is now in its third year of existence and has been able to show that it has a potential to further grow. This is not just in recruiting more students only but also in enhancing its network generally. A first step is to find more partners to go for the DD option.

The course has been re-accredited from the German side very recently. It has been requested to further group the modules such that the number of modules gets reduced, the credit points per module increased and the exam load reduced because of the reduced number of modules. This is a general recommendation made today in accreditations in Germany which will gradually change the structure but not the contents of the course in case this can all be matched with the accreditation of the partnering institution (in our case SWJTU).

Although the course covers a broad range of NDT techniques there is still scope for more that could be provided through new modules. Examples include a possible specialisation in some of the techniques, probability of detection, human factors or NDT applications in various fields such as civil infrastructure, railway engineering, energy generation, aeronautics, to just name a few. This however is only possible to consider once the number of students has further increased and electives can be offered. Currently at least all the basics are taught, such that students are able to grasp the subject they may be following along the research placement as well as the master thesis.

With the graduation of students in 2016 a new era has started which leads to graduates spreading to different places in the world to follow up their professional career. Since many of those graduates will continue to be active in the NDT field it is worth considering an alumni network to be established that may have the opportunity to meet once per year and to allow for further development of the course towards absolute scientific excellence.

Last but not least there is the question on how the scientific output of this course can be further grasped by DIU and the other institutions it is associated with. The surprisingly high

enthusiasm the 2016 graduates gained in performing scientific research consequently leads to the idea on how to use the network of graduates and associated institutions to perform world class level research and getting the graduates further promoted to a doctoral degree. Although DIU has neither research premises nor can award doctoral degrees at present it may still be able to provide its own type or character in scientific research provision and doctoral degree conferment in a way that graduates perform research at the institutions within the DIU NDT network and get a doctoral degree awarded from the academic institutions being within this network as well.

6. Conclusions

Running the DIU NDT master course now for three years and having successfully completed one cohort of students has shown that the course is sound, feasible, realistic and has its clear value and merits. Although getting the course established is initially hard work and also getting it operational is not of an effort to be underestimated. However, the need of such a course is already proven to a first degree and it is not unlikely that this will even become more apparent once the number of graduates and applicants further grows. In that regard further academic and research institutions are invited to join the DIU NDT network, which are able to contribute to the world class standards that this course requests. It is the ambition of this NDT master course and emerging scientific network to provide a platform of highest academic and scientific level within the NDT community. This is provided by the fully flexible DIU system where lecturers can be recruited from virtually any place of the world. This allows at least to invite the best of the best worldwide to join the teaching staff in case they are willing to accept the standard payment conditions that DIU can allow. It currently does not show to be unrealistic to get this course forwarded to one of the best NDT master courses the world has ever seen so far, not just from a scientific but also from an international point of view. For many of the students their stay at DIU in Dresden and Germany is their first experience outside their home country, with life in another culture and also having to fully use another language (mainly English) than their mother tongue. It is enjoyable to see how those students have increasingly improved their English skills along the course, how they possibly even try to learn German as a third language and how they get well adapted into a German society together with mates and other people from other ethnic origins settling into the German society as well. As such any further party being interested to apply and join is most welcome. Courses start annually in October and any further details can be found on the course's website which is:

<http://www.di-uni.de/index.php?id=507>