Iowa State University’s Undergraduate Minor, Online Graduate Certificate and Resource Center in NDE

Nicola Bowler, Brian F. Larson, and Joseph N. Gray

Center for Nondestructive Evaluation, Iowa State University, Ames, IA 50011, USA

Abstract. Nondestructive evaluation is a ‘niche’ subject that is not yet offered as an undergraduate or graduate major in the United States. The undergraduate minor in NDE offered within the College of Engineering at Iowa State University (ISU) provides a unique opportunity for undergraduate aspiring engineers to obtain a qualification in the multi-disciplinary subject of NDE. The minor requires 16 credits of course work within which a core course and laboratory in NDE are compulsory. The industrial sponsors of Iowa State’s Center for Nondestructive Evaluation, and others, strongly support the NDE minor and actively recruit students from this pool. Since 2007 the program has graduated 10 students per year and enrollment is rising. In 2011, ISU’s College of Engineering established an online graduate certificate in NDE, accessible not only to campus-based students but also to practicing engineers via the web. The certificate teaches the fundamentals of three major NDE techniques; eddy-current, ultrasonic and X-ray methods. This paper describes the structure of these programs and plans for development of an online, coursework-only, Master of Engineering in NDE and thesis-based Master of Science degrees in NDE.

Keywords: Nondestructive Evaluation Education, Undergraduate Minor, Online Graduate Certificate

PACS: 01.40.-d, 81.70.-q

INTRODUCTION

Nondestructive Evaluation (NDE) is an essential, high-technology career field and many companies in manufacturing, transport, power engineering and others rely heavily on a well-educated NDE workforce. Many excellent technician training programs and on-the-job training opportunities exist to fill the ranks of inspectors. The field is becoming increasingly technical, however, with computer-modeling being used to develop optimized inspection practices and sophisticated inspection systems being used to push the limits of flaw detectability. Yet, due to the relatively limited size of the NDE career field, it currently does not warrant an engineering undergraduate or graduate major in its own right. Therefore, companies find it necessary to actively promote continuing academic education in their workforce, creating a demand for educational opportunities that are accessible to professional engineers while allowing them to simultaneously meet their work commitments. Online education is inherently portable and convenient for working professionals since it can be accessed anywhere that the internet is available. The Center for NDE at Iowa State University offers a number of online NDE educational opportunities, ranging from an NDT Education Resource Center to full engineering courses offered for credit via online learning. This article provides a brief introduction to the online education activities of the Center for NDE at Iowa State University, as well as providing an overview of the campus-based engineering undergraduate minor in NDE that has existed since 1995.

BACKGROUND

The Center for NDE (CNDE) is a multi-disciplinary research center at Iowa State University (ISU). It does not fall exclusively under any one of ISU’s eight colleges but is strongly linked to many of them. CNDE draws expertise from various disciplines across the university (e.g. materials science; electrical, mechanical and aerospace engineering; physics; statistics; education and others) and many of its researchers hold concurrent academic appointments in university departments. Diversity in the mix of CNDE personnel has led not only to accomplishments in research but also to the development of a number of significant educational offerings.
UNDERGRADUATE MINOR IN NDE

The undergraduate minor in NDE at Iowa State University is a unique opportunity for undergraduates to obtain a qualification in nondestructive evaluation while pursuing their bachelor degree in an engineering program. The undergraduate minor in NDE, in existence since 1995, consists of 16 credits. Note, one course credit is equivalent to approximately 15 hours of classroom instruction and one laboratory credit involves approximately 45 hours of laboratory work. The 16 credits that comprise the undergraduate minor in NDE are structured as follows.

- One compulsory 3-credit course “Principles of Nondestructive Evaluation”, and its accompanying 1-credit laboratory,
- At least two out of three other 3- or 4-credit NDE-specific courses, or a semester of independent study, and
- One other 3-credit course that may be another NDE-specific courses, or one selected from an approved list of NDE-related subjects.

The compulsory course “Principles of Nondestructive Testing” serves as an introduction to topics and techniques in NDE. It is also offered online, being suitable for professional engineers encountering the field of NDE for the first time, for example.

The majority of students who enroll in the NDE minor pursue a semester of independent study. This is a creative, research-based study working with a mentor at CNDE, with a time commitment of approximately 10 hours per week for 15 weeks. A typical study includes laboratory work, a survey of relevant literature, and writing a report that is the basis for the awarded grade. The program of independent study allows the student to engage in a longer-term, research-based activity that goes beyond classroom learning. It provides valuable experience for any aspiring engineer while also contributing towards the NDE minor.

Independent study projects are available in various of the NDE techniques including ultrasonic, X-ray, eddy-current, magnetic, visual, thermal, microwave and capacitive NDE. Project topics are mutually agreed between the student and mentor and can be tailored to particular interests that a student may have.

The number of students enrolled in the compulsory course for the undergraduate minor has remained between 35 and 40 students per class from 2007 through 2012, but saw a jump to 55 students in 2013, Figure 1(a). The number of students graduating with the NDE minor, since it began, is shown in Figure 1(b). Averaged over the past 5 years, the number of students graduating with the NDE minor per year is 9.

![Figure 1](image-url)
ONLINE GRADUATE EDUCATION IN NDE

For in-depth learning, graduate courses in NDE are offered online. These may be taken either individually, to improve knowledge in a specific area, or in certain combinations to accumulate thirteen or more credits of graduate coursework in approved courses in order to obtain a Graduate Certificate in NDE, in existence since 2011.

The Graduate Certificate in NDE is targeted towards professionals working in numerous industrial sectors that rely on NDE for safe and efficient operation and include, but are not limited to, manufacturing, transport and power engineering. Applicants must have a Bachelor degree in engineering or a physical science and must satisfy the prerequisites for the individual courses that comprise the certificate. In particular, an understanding of three-dimensional vector calculus and differential equations is necessary.

The Certificate teaches the fundamentals of three major NDE techniques; eddy-current, ultrasonic and X-ray methods. The program does not offer certification in NDE inspection methods, but focuses on the physical principles upon which these three major NDE inspection techniques are founded. Courses are taught by faculty and adjunct faculty in the College of Engineering who conduct research programs at Iowa State’s Center for NDE.

The Graduate Certificate in NDE consists of

- One compulsory 4-credit course “Fundamentals of Nondestructive Evaluation”,
- At least two out of three other 3-credit NDE-specific courses, and
- One other 3-credit course that may be the third of the NDE-specific courses, or another course from an approved list of NDE-related subjects.

The compulsory course gives a graduate-level introductory treatment of the principles of several major NDE techniques; ultrasonic, X-ray, and eddy current NDE. The treatment of these three techniques is developed in detail in additional 3-credit NDE-specific courses, whose titles are

- “Waves in Elastic Solids with Application to NDE”,
- “Penetrating Radiation Methods in NDE”, and
- “Eddy Current NDE”.

As mentioned above, at least two of these three courses must be taken in order to fulfill requirements for the certificate. The required minimum of thirteen total credit hours of graduate coursework may then be completed by taking either the third of the NDE-specific courses listed directly above, or by taking an approved NDE-related course on a topic such as mechanics of materials, fracture and fatigue, mechanics of polymer composites, finite-element modeling applications, applied statistics, signal processing and image processing.

Technological Tools Enhance Student Learning

Iowa State’s Engineering Online Learning facility offers fully web-based learning. Classroom lectures are made available in real time as streaming video or may be watched later at the student’s convenience. Notes written by the instructor during class time are saved in electronic form and may be downloaded along with the lecture slides. Discussion boards, class announcements, assignments and a personal grade-book are all handled by the same portal that archives the lecture materials. The classroom technology enables movies and model-based simulations to be integrated with traditional lecture materials. In summary, distance students are able to participate in all aspects of the course, even in making interactive, real-time presentations to the class.

Simulations

A number of simulations (“simlets”) have been developed for teaching specific concepts in ultrasonic and X-ray NDE. One example simlet applicable to ultrasonic NDE is shown in Figure 2(a) in which the pressure profile from a transducer is shown for various frequencies. The near and far fields are clearly seen and illustrate the property of increasing distance from the transducer as the frequency is increased. The student can adjust the probe parameters and visualize their impact on the location of the far/near field transition. In Figure 2(b) the focusing effect of surface curvature is shown. The student can alter the location of the transducer and visualize the volume of material that is probed.
FIGURE 2. (a) Simulated output sound field entering a test piece from an ultrasonic transducer at various frequencies. As the frequency increases, the location of the far/near field moves away from the transducer; (b) Simulation showing the effect of surface curvature on the re-focusing of the ultrasound field penetrating into a material.

The simlet shown in Figure 3 is designed to calculate levels of radiation exposure for typical industrial X-ray sources. This information may then be used to calculate the required shielding to meet radiation exposure levels around the exterior of a biological shield, and the performance of various shielding materials can be compared. The power of the tube can be varied in the simlet, to account for a range of typical commercial tubes and isotope sources.

FIGURE 3. ‘Simlet’ for calculating levels of radiation exposure. The dose in REM is shown according to a color scale for a selected duration of exposure, in this example 1 second. Orange represents 35 rem/sec (near the tube) and yellow represents 5 rem/sec.
In Figure 4, the density of electrical eddy currents in a metal test piece, below an eddy current surface coil, is visualized by means of another simlet.

**FIGURE 4.** Simulated distribution of eddy currents in a metal test-piece below a surface coil.

### Assignments

For the course “Eddy Current Nondestructive Evaluation”, three software-based assignments have been created in order to address the question of how to make available, to off-campus students, investigations such as might be performed in the traditional laboratory. Development of the assignments was supported by ASNT’s Faculty Grant Award 2008 [1]. Example output from the software [2] is shown in Figure 5. The assignments have been perceived by students to significantly assist their understanding of the course material, as reflected in selected comments given below:

- “The software gives me visual understanding of parameter’s (such as lift-off, conductivity etc.) effect on the impedance curve – very nice!”
- “[The software] “made me think deeply about what phenomena are taking place”.
- “as someone working in industry, I'm very glad to see simulation software being incorporated into university course material”

In another innovation, researchers at Iowa State’s Center for NDE have partnered with VM products, Inc. to design and build experiment kits that will be loaned to students and allow them to perform eddy-current experiments by connecting the kit to their own personal computer. In this way, the experience of investigative laboratory assignments will be replicated for students who do not have ready access to a laboratory.

### Master of Science and Master of Engineering in NDE

Due to the presence of CNDE, and building on the existing graduate certificate in NDE, Iowa State University has the capability of offering, supporting and populating Master degrees in nondestructive evaluation. For campus-based students, it is planned to develop and offer a thesis-based Master of Science in NDE. For NDT professionals and others who wish to pursue online learning, a completely coursework-based online Master of Engineering in NDE will be offered.
FIGURE 5. Example output from software-based assignments; simulated lift-off curves for an eddy current coil moved from the surface of metal test-pieces with various conductivity values, to the air point. Results are normalized with respect to the inductive reactance of the coil in air.

ONLINE NDE EDUCATION RESOURCE CENTER

Perhaps the most visible educational offering that CNDE has had a major hand in developing is the NDE Education Resource Center, available on the internet. A screen capture of the website’s homepage is shown in Figure 6. The primary goal of the internet material is to enhance learning in NDT technician training programs at community colleges and to introduce primary school students and counselors to the field of NDT. The online materials were developed by the Collaboration for NDT Education, which includes Cowley Community College, Arkansas City, KS; Ridgewater College, Hutchinson, MN; Salt Lake Community College, Salt Lake City, UT; Southeast Community College, Milford, NE, and Iowa State University, Ames, IA. Initial funding for the development of the educational materials was provided by the National Science Foundation, and the site is now maintained with the generous support of a number of site sponsors.

The materials have been well received and are being used by students and other individuals around the world. The website usage has grown steadily over the years and currently receives over 350,000 visits and over five million hits each month, Figure 7. A number of educational institutions are using the material to supplement their NDT programs. Feedback from site users via an on-line survey indicates that the materials are also being used in related technology programs, such as manufacturing, welding, airframe, power plant and chemical processing, and by the general NDT community at large. In addition, much of the information covering basic scientific principals is proving useful to middle and high school students and is exposing them to NDT as a career field at the same time.

Improvements continue to be made to the site. Work is currently underway to add a section that discusses various aspects of visual inspection and to complete development of a primer in materials and processing. The primer is intended to provide NDT personnel with a basic understanding of materials manufacturing and the types of defects that can occur in manufacturing processes. Future plans include adding material on some of the newer NDT techniques, such as phased-array ultrasonic inspection and terahertz inspection.
FIGURE 6. Screen capture of the NDT Resource Center website's home page.

FIGURE 7. Graph showing growth in website usage. A visit is recorded whenever someone brings up the site in his or her browser. A hit is recorded whenever the person clicks on something, such as a button or link on the site.

MORE INFORMATION

1. Nicola Bowler, Director of Certificate Studies. E-mail: ndeonline@iastate.edu
2. Iowa State’s Engineering Online Learning website: www.elo.iastate.edu
3. NDT Education Resource Center: www.ndt-ed.org
4. Iowa State’s Center for NDE website: www.cnde.iastate.edu
CONCLUSION

Approximately ten students per year graduate with an undergraduate minor in NDE from Iowa State University. An online graduate certificate was created in 2011, targeting the engineering professional who wishes to pursue graduate studies in NDE. Two Master’s programs in NDE are planned; one thesis-based for on-campus students and one course-based for online delivery. University-level education in NDE forms an important complement to the process of certification of NDT inspectors, educating the future engineering workforce in the principles of NDE inspection methods for materials processing, in-service inspection and for optimal scheduling of maintenance and repair.

ACKNOWLEDGMENTS

The courses “Penetrating Radiation Methods in NDE” and “Eddy Current NDE” were first developed under funding from the US Air Force. The virtual eddy current instrument was developed under the guidance of John Bowler, in collaboration with VM Products, Inc, Tacoma, WA and funded by Iowa State University’s Engineering Computing Fee Capital Projects Fund. Nicola Bowler received ASNT’s Faculty Grant Award 2008 to support the incorporation of model-based simulations into the eddy current course materials.

REFERENCES

1. N. Bowler, “Graduate Course in Eddy Current NDE for Distance Learning”, ASNT Faculty Grant Award 2008.
2. TEDDY V1.2, developed by T. P. Theodoulidis (theodoul@ieee.org), is designed to simulate a number of eddy current inspections by computing the impedance of a coil over layered planar structures (probe coil) or inside and around layered cylindrical and spherical structures (bobbin-ID and encircling-OD coils). It is provided to the NDT community as a freeware on the condition that its use for publishing results will be referenced.