Undergraduate Research As An Enhanced Educational Tool and A Transition Mechanism for Post-Graduate Studies

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Research experience for undergraduates is of great importance not only for conducting research on a topic that has impact on a current research activity, but also as a tool to enhance undergraduate education. During the past decade, undergraduate research in nuclear engineering was irregular, a case-to-case event, based on individuals' interest. Such previous experience has shown that research was helpful in providing the undergraduates with experimental and computational expertise, insight on the importance of research for continuing education, and the possibility of advanced research that leads to graduate studies. In the undergraduate research cases that have been conducted in the Department of Nuclear Engineering at NC State University, it turned out that most of the undergraduates who had been engaged in research proceeded into graduate studies, either to the master or the doctoral level. Because of these facts, and the gained experience, an undergraduate research program was initiated in the summer of 1996. The program provides a research experience and helps the students to be involved in applications relevant to their studies. The 1996 program provided research projects for seven students in various nuclear engineering areas, two funded by the Department of Nuclear Engineering and five funded by the faculty through their research contracts. Areas covered are reactor physics, thermal hydraulics, radiological engineering, nuclear materials, plasma engineering, radiation applications, and plasma thrusters. Four students chose to continue their research during the academic year, applied to the graduate program, and have been accepted. This paper summarizes the undergraduate research program, how the program serves as an enhanced undergraduate educational tool, and how it helps in preparing selected students for advanced post-graduate studies.

I. INTRODUCTION

In many engineering disciplines, research at the undergraduate level can be available to provide research experience that might lead to graduate research. Additionally, it might be used as an educational tool to enhance experimental and computational skills, prepare students for graduate studies and research, and to enhance education via better understanding of theory and applications through research experience. Because of such needs, an undergraduate research program was initiated at NC State University, Department of Nuclear Engineering, in the summer of 1996. The program was successful in providing undergraduate research in the major research thrusts of reactor physics, thermal hydraulics, radiological engineering, nuclear materials, plasma engineering, and radiation applications. Successfully, students research was funded either from individual faculty research contracts or directly from local resources. In order to achieve educational goals, as well as research, the program has been designed to involve students in research of direct relevance to the nuclear engineering curriculum, and advances into graduate research studies. Selected students were encouraged to continue on the program during the academic year, where they developed advanced techniques and higher level of expertise.

II. RESEARCH ACTIVITY AND DIRECTIONS

The following sections will provide a short summary of each undergraduate research topic, subdivided in fission reactors and applications, radioisotopes applications, plasma engineering, and nuclear materials.

II.1 FISSION REACTORS AND APPLICATIONS

II.1.1 Dynamic Rod Worth Measurement (DRWM)

The Dynamic Rod Worth Measurement technique is an alternative method for measuring control rod worth during zero power physics testing. This technique reduces the experiment duration if rods are ramped in with maximum stepping rates. The dropped rod method was the first part of the student's research, followed by a determination of ex-core detector response factors that necessitates utilization of transport theory and employing various computer codes (DORT/TORT codes).[1] As a result of this research, it has been concluded that the dropped rod method can be utilized for rod worth measurement. Additionally, a three-dimensional model of the core will be developed using the TORT code to determine the ex-core detector response factors.[2]

II.1.2 Reactor Power Plant Simulation

A reactor power plant simulation code has been developed for the CE 80+ Combustion Plant.[3] The input structure for this code uses a FORTRAN-90 code to create a menu structure, and a MATLAB package was used to create graphics. The output structure consists of the pressurizer, core and balance of plant graphs. This code was written for a PC and can simulate a nuclear power plant during an accident transient. It was necessary to compile the code on the

NCSU EOS Sun and DEC workstations for class work. An interface has been developed to link to a user-friendly input changes and a graphical interface to display output data.[4]

II.1.3 Prompt Gamma Facility for Boron Neutron Capture Therapy

The Prompt Gamma facility of the NCSU PULSTAR reactor has been used to determine the amount of boron in certain samples. These samples were mice tissues injected with boron-10. Thermal neutrons are channeled through a beam tube towards the sample. The system was calibrated through the use of neutron radiography, and dimensions and geometry of the beam were determined in order to precisely adjust the location of the biological sample. Calibration curves were obtained for the samples and tests were conducted on unknown chicken liver samples to measure the amount of boron. In collaboration with UNC-Chapel Hill, it has been shown that the PULSTAR reactor could be used as a boron neutron capture therapy facility.[5]

II.2 RADIOISOTOPE APPLICATIONS IN NUCLEAR WELL LOGGING

A known and efficient application of radioisotopes is nuclear well logging. A project has been conducted on using this technique to generate a library based on neutron absorption and scattering cross sections for various materials of a typical oil well. A set of experiments were conducted using a neutron source immersed in a pool that contains different concentrations of either aluminum, chlorine or sodium in a solution. A detection system was installed to obtain the gamma spectrum. Several Monte Carlo simulation codes were used for data analysis and comparison with experimental results.[6]

II.3 NUCLEAR MATERIALS: AUTOMATED BALL INDENTATION TECHNIQUE

Developing new techniques to assess the behavior of nuclear materials is a necessity for in-situ measurement of the stress-strain of irradiated materials. The Automated Ball Indentation technique (also known as nano-indentation) can provide nuclear reactor in-vessel testing. Measuring the resistance of penetration into a material can be automated via a ball indentation tester coupled to a linear voltage displacement transducer. The project consists of the use of such an automated indentation technique to measure the stress-strain curves of various nuclear materials, from which yield strength, tensile strength and modulus of elasticity could be obtained. Research was conducted on zirconium and titanium samples, and calibration graphs were obtained.[7]

II.4 PLASMA ENGINEERING AND APPLICATIONS

II.4.1 Scaling Laws of Electrothermal Capillary Discharge Plasmas

Electrothermal plasma sources may be used as launching devices, or as pre-injectors for electromagnetic or electrothermal-chemical launchers. The characteristics of the injected plasma may effect the performance of the plasma armature in electromagnetic launchers, or the combustion processes in electrothermal-chemical launchers. Much of the performance depends on the plasma parameters inside the plasma source, which is a capillary discharge. In order to

verify models and experimental results, scaling laws were developed to provide a quick estimate of plasma parameters.[8] A computer code was written based on these scaling laws, but takes the measured discharge current as an input to the code. Thus, time-dependent parameters could be obtained. The code predicts the plasma temperature, pressure, density, radiation energy and ablated mass. Code predictions have shown good agreement with prediction of another 1-D, time dependent code, ODIN,[9] and experimental results.[10]

II.4.2 Pulse Forming Network for the Coaxial Plasma Gun

The magnetized coaxial plasma source is a device designed for the generation of energetic plasma stream flows.[11] It has a wide variety of applications including, but not limited to, advanced thrusters for electric propulsion, astrophysical jets, magnetic fusion, large-scale plasma etching and deposition, etc. In order to achieve a longer pulse length of 10 ms, a pulse forming network has been designed through a series of optimization techniques. The pulse forming network is composed of coupling inductors on each pair of capacitors, an ignitron switch, and a matching transformer coupled to the plasma load. The computer code SPICE has been used to simulate the circuit elements, and predict the current wave form. The new pulse forming network provides a flat-top current pulse length of 6 ms over a full discharge period of 9 ms.[12]

III. RESEARCH IMPACT ON UNDERGRADUATE EDUCATION

The initiated undergraduate research program has resulted in three major achievements, providing research experience, implementing research findings into the nuclear engineering undergraduate curriculum, and advancing the research to the graduate level. For example, the Reactor Power Plant Simulation Code is currently used by students in NE201 Introduction to Nuclear Engineering. The Automated Ball Indentation system is used in the nuclear engineering materials courses. The Boron Neutron Capture Therapy project evolved into a senior design project lead by the same person who conducted the primary research. Plasma engineering research projects are now part of plasma application and fusion technology courses. Four of the undergraduate students chooses to continue their research during the academic year, they applied to the nuclear engineering graduate program, and have been accepted.

IV. CONCLUSIONS

The undergraduate research program has been successful in providing research experience to the undergraduates, and evolved into a useful educational mechanism that implemented many of these projects into the undergraduate curriculum. It is also an efficient transition towards graduate research.

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BIOGRAPHIES

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