AC 2007-1589: TIERED MENTORING IN A CROSS-DISCIPLINARY AND MULTI-INSTITUTIONAL RESEARCH PROJECT

Karen Crosby, Southern University

Dr. Karen E. Crosby received her Ph.D. degree in Engineering Science from Louisiana State University in 2000. She is currently an Associate Professor of Mechanical Engineering at Southern University. Dr. Crosby's expertise is in the area of materials science and mechanics, including mechanical property and microstructural characterization and deformation and fracture of engineering materials. Dr. Crosby's research activities have allowed collaboration with universities, private companies, and several federal governmental laboratories and agencies, including Los Alamos National Laboratory, Oak Ridge National Laboratory, NASA/George C. Marshall Space Flight Center and NASA/Glenn Research Center. She has five papers published in refereed journals and other refereed publications and she has authored numerous conference papers and technical reports. She has received a number of awards for educational excellence including Most Outstanding Faculty from the SU Mechanical Engineering department four years in a row (2001-2005) and the 2005 National Women of Color in Technology Educational Leadership Award.

Samuel Ibekwe, Southern University

Dr. Samuel Ibekwe is currently a professor and chairman of the Department of Mechanical Engineering at Southern University. One of his current research projects, sponsored by Louisiana Board of Regents and the Department of Defense (DoD) is on "High Temperature Materials Research: Study of Elastic Anomaly and Grain Agglomeration Features in the Superalloy IN738LC." His research work has been primarily on mechanical characterization of engineering materials, and impact damage of polymer composite materials. His past funded research projects have been from the Louisiana Board of Regents, National Science Foundation, DoD, the Louisiana Space Consortium (LaSPACE), and private industries. His has over 30 publications in the related areas. In addition to research, he is also a recognized expert in minority higher education. A past recipient of the department’s faculty of the year award, ASME Eckart service award and Louisiana Engineering Society’s Engineering Faculty Professionalism Award, Dr. Ibekwe is a Louisiana State-registered professional engineer who holds one U.S. design patent.

Guoqiang Li, Southern University

Dr. Guoqiang Li is currently an Assistant Professor of Mechanical Engineering at both SU and Louisiana State University (LSU) (Joint Faculty Appointment). His expertise is in composite materials and solid mechanics. He has 68 refereed journal publications in his research area. His research has been supported by various funding agencies, including FHWA, NGA, USDA, LaBoR, LTRC, NASA-BoR/DART, LaSpace, MBTC, etc. He has received 23 research grants as PI, Co-PI, or key investigator. In addition to research, he has also been involved in academic services. He has reviewed over 30 papers for 10 refereed journals and served as Co-Chair for ASME/Petroleum Division/Offshore Operation Symposium. He has received 13 awards from ASME and other agencies for his research and service. Fifteen undergraduate students, mainly minority students from SU and LSU have conducted research under Dr. Li's guidance. Among them, five minority students have published four refereed journal papers as leading authors or coauthors. He has received the 2003 LSU Campus Outstanding Mentor Award by the Louis-Stock Louisiana Alliance for Minority Participation (LS-LAMP).

Su-Seng Pang, Louisiana State University-Baton Rouge

Dr. Su-Seng Pang received his Ph.D. degree in Mechanical Engineering from U.C. Berkeley in 1987. Currently, Dr. Pang is the Jack Holmes Professor of Mechanical Engineering and Associate Vice Chancellor for Strategic Initiatives at LSU. He is a Fellow of the American Society of Mechanical Engineers (ASME). Dr. Pang is a recognized expert in the composite materials

research field. He has published over 160 journal papers/conference proceedings in the areas of composite materials and structures, pressure vessel and piping, and various joining technologies. Currently, he is an editorial board member of the journal Composites -- Part B: Engineering; Technical Program Committee Member of SPE Joining of Plastics and Composites Group; ACAP Board of Director Member; Symposium Co-Chairman and Conference Sessions Developer of ICCE/1-12, etc. He has been the PI/Co-PI/Key Investigator for over 80 research/educational projects funded by NSF, NASA, ATP/NIST, U.S. Navy, Louisiana Board of Regents, various industries, etc. Since 1996, he has received 27 national/regional awards in research and education, including: 2005 LSU H.M. Hub Cotton Award for Faculty Excellence; 2003 LSU Forest Dent Smith Making the Difference Award; 2002 ACAP Distinguished Achievement Award (Association of Chinese-American Professionals); 1999 Carnegie/CASE Louisiana Professor of the Year; 1998 AAAS National Mentor Award (American Association for the Advancement of Science); 1998 Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring (NSF/White House); 1998 LSU Distinguished Faculty Award; 1997 Tibbetts Award for SBIR Model of Excellence (U.S. Small Business Administration/White House), and 1996 ASEE National Minorities in Engineering Award.

Kun Lian, Center for Advanced Microstructures and Devices (CAMD)

Dr. Kun Lian is currently an Assistant Professor at CAMD. He received his M.S. and Ph.D. degrees in Materials Science from Louisiana State University at 1991 and 1995, respectively. Then, he became a Postdoctoral Research Fellow at Nuclear Engineering Department at University of Michigan at 1996. He joined Microfabrication Group of CAMD at the end of 1997. At CAMD, he focuses his researches on MEMS materials, especially on nickel based LIGA materials. His research efforts have been focused on LIGA MEMS fabricating techniques, component reliability evaluation, LIGA MEMS nickel structure fatigue testing, and thermal stability study. His has been PI and co-PI for many research grants for the last 8 years, most of them from DARPA to support the study of mechanical properties and thermal stability of LIGA nickel materials. He also developed plated Ni-Re alloy system for high temperature LIGA MEMS applications. Besides the fabrication and mechanical property characterization, he also specialized in investigation of corrosion/stress corrosion cracking behavior of nickel based materials. He published many papers on LIGA MEMS nickel materials fabricating, surface mechanical property evaluation, new method for LIGA nickel fatigue testing, thermal stability of LIGA nano-crystalline nickel based materials, tensile, fatigue and creep properties of LIGA Ni structures, and relationship between processing parameters-LIGA nickel microstructures-resulting mechanical properties.

Tiered Mentoring in a Cross-disciplinary and Multi-institutional Research Project

Abstract

A multi-institutional research project titled "Towards Miniaturization of the Naval Nuclear Propulsion Reactors: Novel Processing Routes of Fabricating Microstructures on Pressurized Water Reactors" has recently embarked. This research is performed cooperatively between the lead investigators at Southern University which is an HBCU (historically black college or university), researchers at Louisiana State University which is the state's flagship school, and CAMD (the Center for Advanced Microstructures and Devices) which is a state-of-the-art research and technical facility–all located in Baton Rouge, Louisiana. The major goal of this three-year project is to develop innovative methods to enhance performance of Naval reactors by optimizing manufacturing techniques for complex structures made with high performance materials that can withstand extreme high pressure and elevated temperature. This will be accomplished by unifying the expertise of the team in LIGA (a German acronym meaning "lithography, electroplating, and molding"), simulations of the thermal transport in complex systems, microsample testing, design optimization, and comprehensive microstructural and macrostructural characterization of the proposed structures.

In addition to the faculty and technical personnel, students will participate in a significant way in this project. Graduate and undergraduate research assistants will be employed to aide in the technical aspects of the research. Additionally, these students will also lead in the educational objectives of the project. The team seeks to develop a "research-oriented approach" designed to attract and retain a greater number of high-quality minority students in Science, Technology, Engineering, and Mathematics (STEM) disciplines. This will be accomplished by providing training for graduate and undergraduate researchers in the fundamental area of design, fabrication techniques of microstructures, thermo-mechanical analysis, materials characterization, and advanced experimental techniques. Additionally, there is a tiered mentoring process whereby the faculty and technical staff are mentors to the graduate students, the graduate students are mentors to the undergraduates, and the undergraduates are charged with carrying the mentoring to local high schools. The undergraduates include students of Civil, Electrical, and Mechanical Engineering who are involved in different aspects of this project and others. They are performing demonstrations and making presentations in the area high schools to spark interest in Engineering and to instill an appreciation of the cross-disciplinary nature of research. It is certain that these interactions will impact recruitment and retention while enabling the development of interested students and skilled researchers which will provide a great socio-economic benefit to the nation.

Introduction

Of course research is a fertile ground for educational development. It is well documented that the experience of conducting research and scientific inquiry helps undergraduate students to excel in undergraduate studies and prepares them for the rigors of graduate-level experimentation and analysis. Additionally, other opportunities rest between the layers of research. Recruitment

and retention outcomes can be achieved through coordinated outreach activities which foster skills in leadership and communication. Compared to academic preparedness, the potential for professional development in undergraduate as well as graduate students is much less acknowledged. Corporate representatives are calling for engineering educators to increase focus on the development of professional skills in addition to academic excellence in students of engineering in order to meet the challenges of the workforce. University research provides one avenue for meeting these goals.

Two Louisiana universities are taking advantage of their close proximity to each other and to a unique advanced research facility. Southern University and Louisiana State University are collaborating to explore new manufacturing methods to enhance performance of naval nuclear reactors. Educational goals correspond to each research goal of the project. Some of these goals are met through the employment of graduate and undergraduate students as research assistants to the participating faculty. As usual, the faculty members mentor the graduate students in their research. The graduate students thusly mentor the undergraduate students through their research. The last link in the chain is the mentoring and outreach activities conducted by the undergraduate assistants at area high schools.

Such research and education activities will be disseminated through the development of interdisciplinary and cutting edge science/technology based curriculum, involvement of the undergraduate and graduate students in the year-round research projects, exposure of the state-of-the-art laboratory facilities, workshops for integrating computer and simulation techniques and through community services that involve high school students. With the active involvement of the investigators who are responsible for propagating the technology and knowledge obtained from this project into class teaching, mentoring, students advising and human resource development. The team hopes it is preparing and educating the next generation of highly skilled personnel that can be successfully recruited in the nation's industries, academia and research workforce.

This paper will briefly summarize the technical aspects of the research project. The next purpose is to examine the benefits of the mentoring tiers. Finally, the preliminary outcomes will be addressed and discussion will end with a look into measurement of future outcomes.

Towards miniaturization

Research Team

The team leading this endeavor includes faculty from the College of Engineering/Department of Mechanical Engineering of the lead institution, Southern University which is a Historically Black College/University (HBCU) and the State's flagship school, Louisiana State University, both located in Baton Rouge, Louisiana. Rounding out the team is a group of researchers from the unique Center for Advanced Microstructures and Devices (CAMD) also located in Baton Rouge, Louisiana. CAMD is a synchrotron radiation (SR) facility, one of only eight SR sources in the nation and the only state-funded source. Synchrotron radiation is "light" (electro-magnetic radiation) emitted from electrons moving at near the speed of light on macroscopic circular orbits (synchrotrons, storage rings). The beam is directed at bends along the orbit to stations along the

periphery where the synchrotron radiation is used to perform various experiments and tasks from microstructural characterization to microfabrication. See figure 1.

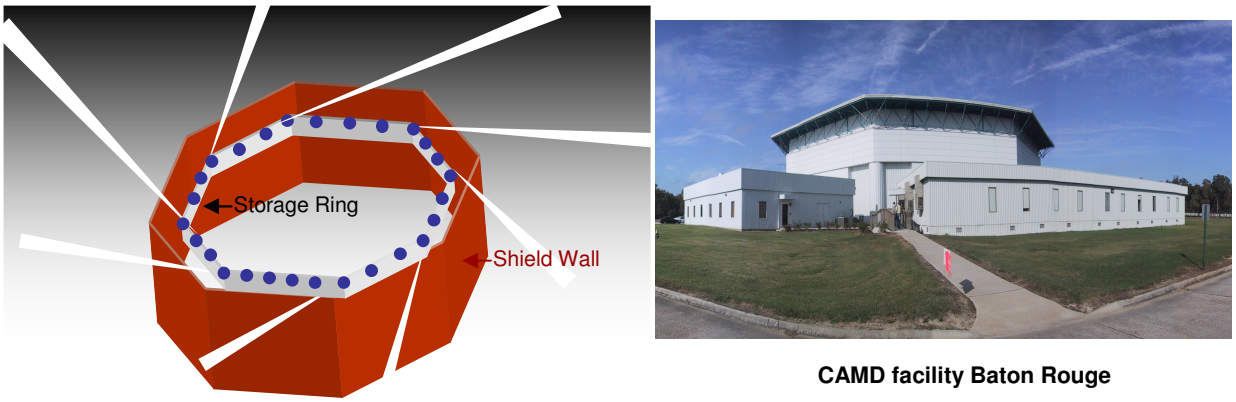

Figure 1. Illustration of the synchrotron radiation source inside the CAMD facility shown.[1]

The team combines expertise among the faculty in manufacturing, thermal science, materials science, and design. From the CAMD researchers the team gains experience in the microfabrication technique LIGA (a German acronym for "Lithographie, Galvanoformung, Abformung" that means lithography, electroplating and molding). The student participants include juniors and seniors from the Departments of Civil and Environmental Engineering, Electrical Engineering, and Mechanical Engineering and graduate students in the Department of Mechanical Engineering at Southern University.

Research Goal

The purpose of the research is to redesign the heat exchangers of pressurized water reactors (PWR) to increase heat transfer between heated radioactive water and the non-radioactive feedwater inside the steam generator (shown in Figure 2). The function of the steam generators is to transfer the heat from the primary coolant to the secondary feedwater to generate steam for the turbine generator set. Steam generators for the PWR design are shell and tube heat exchangers with high-pressure primary water passing through the tube side and lower pressure secondary feedwater as well as steam passing through the shell side. Therefore, increasing the efficiency of heat exchange is a key issue in improving the design of steam generator.

It is well known that larger heat exchanger interface will dramatically increase heat-exchanging efficiency. Heat transfer augmentation by pin-fins (illustrated in Figure 3) can be several-fold as compared to the configurations without them. Any improvement in the efficiency of the heat exchanger and reduction in their size would therefore directly translate into economic benefits.[3] As compared to macroscale structures, microstructures have higher surface area to volume ratio. Using microfabrication techniques, such as LIGA, micro-molding or electroplating, some special microstructures can be fabricated around the tubes in the heat exchanger of PWR to increase the heat-exchanging efficiency and reduce the overall size of the heat-exchanger for the given heat transfer rates. The team is working to complete high fidelity simulations of the thermal transport

in the entire system, optimal design of microstructure patterns and optimization of the manufacturing of these complex microstructures.

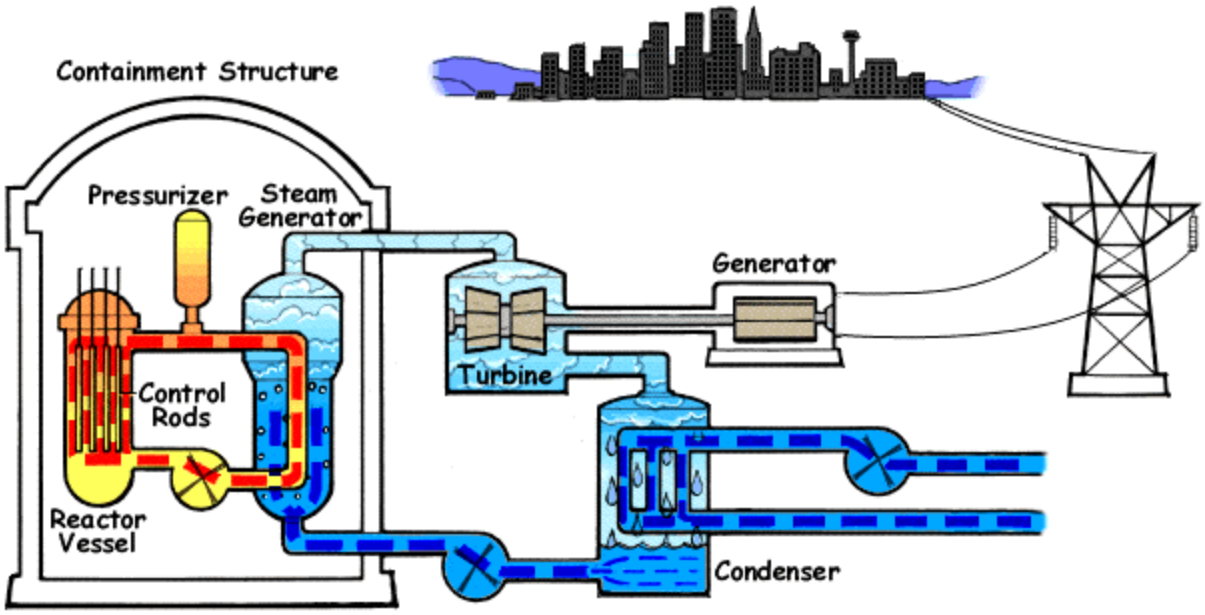

Figure 2: Schematic of PWR coolant systems.[2]
Pressurized hot water from the reactor is used to heat feedwater in the steam generator to form steam which turns the blades of the turbine, therefore generating electricity.

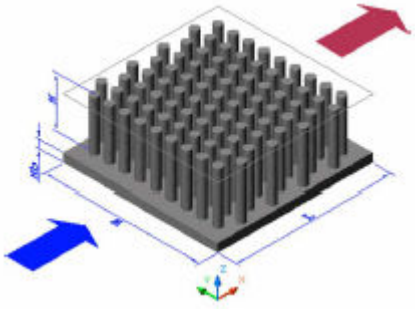

Figure 3: An assembly of micro pin fins to enhance the surface heat transfer by increasing surface area.[4]

Education and Training

In addition to technical research, education and human resource development is another impact task in which, better educational opportunities, and exposure to cutting edge research technologies has been emphasized for minority students that are planning to earn an engineering or science undergraduate or graduate degrees. Through this project, the research experience of minority students is being improved so that they can reach their full academic potential and

compete successfully for the available high technology oriented career opportunities. The motivation here is to (a) develop a "research-oriented approach", (b) retain a greater number of high quality students, and, (c) familiarize these students with the state-of-the-art multi-disciplinary research activities. In order to achieve the objective of this project, a synergistic approach is used in which the research aspect of the proposed work is integrated with the education and human resource development of minority graduate and undergraduate students.

The specific interrelated research and educational tasks are:

- Development of microfabrication techniques for producing prototype micromechanical structures in complex engineered materials:

  Research Aspect: Employment of LIGA processes on curved surfaces is still in the state of infancy. The microfabrication process for curved surfaces will involve development of novel flexible masks and rotating substrates.

  Education Aspect: The students will be trained at CAMD research facilities to microfabricate simple features using LIGA techniques. They will also participate in the summer workshops offered at CAMD.

- Employment of optimal fabrication parameters and surface processing techniques to increase mechanical properties of microstructures under extreme high pressure/temperature:

  Research Aspect: Material selection processes for such harsh environments (high pressure and temperature) are well known for macroscale structures. However, such implications for microstructures remain to be investigated.

  Education Aspect: The students will be trained at LSU as well as SU through their undergraduate and graduate theoretical courses and lab works in the areas of Material Science. The course work projects would also involve usage of CAMD facilities for material selection and design.

- Simulation of the thermal transport and heat transfer behavior in complex systems:

  Research Aspect: Multiscale calculations that involve length scales spanning from the microstructure pin-fin dimensions to the overall heat exchanger dimensions pose several computational and algorithmic challenges. Applications and numerical algorithms to address such multiscale issues will be investigated.

  Education Aspect: The students will be trained through workshops and short courses on the simulation techniques and software packages for heat exchanger problems.

- Optimal design for the geometry and arrangement of the microstructures in order to achieve maximum efficiency:

  Research Aspect: Thermodynamic analysis and design optimization of complex pin-fin structures in the heat-exchanger systems has been done only at the macroscopic details. Such analyses that integrate the microscale to the overall system are rare.

  Education Aspect: The students will be educated on the numerical optimization, design and thermodynamic analysis tools through undergraduate and graduate coursework offered at SU and LSU.

- Experimental techniques for the local material strength behavior of microstructures (pin fins) and the global structural properties of the overall system:

  Research Aspect: Such experimental techniques involve characterization of the fabricated prototype structures, e.g. measurement of the displacement and strain on micromechanical systems, quantification of fatigue properties etc.

  Education Aspect: The students will learn various experimental methods to determine mechanical strength of structures (both macro-scale and microscopic level) at SU, LSU and CAMD experimental facilities.

Mentoring and Outreach

The undergraduate and graduate students participating in this project receive regular training and instruction from the faculty participants. However, a very important part of the organization of the project is the interactions between the graduate students and the undergraduate students. Each undergraduate research scholar is required to meet once per week with his or her graduate mentor. They discuss the individual tasks and overall progress of the project. The graduate students provide much of the training the undergraduate students receive in conducting the on-campus experiments. These interactions provide the graduate students the opportunity to supervise a subordinate and to provide encouragement and feedback. It is also anticipated that they can encourage undergraduate students to pursue graduate degrees. The undergraduate student benefits from the interaction by having someone closer to their peer group to act as a role model and guide in addition to the more experienced faculty.

The undergraduate students also have the chance to act as role models and guides to their sub-peer group through outreach to local high schools. To date, all of the scholars have hailed from Baton Rouge and surrounding areas. Therefore, to make it easier for the students they are required to schedule visits to the high schools from which they graduated. The students are themselves responsible for making the contacts, coordinating with the teachers and administrators, and scheduling the visits. It is believed that this will enhance their communication skills and make them more independent. The students present a variety of topics. Some have presented aspects of their research. Some have demonstrated experiments and others have simply talked about engineering and encouraged the high-school students to consider engineering and technology careers. They have also assisted with science fairs by acting as student evaluators and project mentors.

One illustration of how these activities have helped one scholar is in the development of oral communication skill. One student was terrified of speaking publicly. The student almost fell to pieces during a required presentation to the faculty. The student was encouraged to make the first outreach visit along with a group of other students and faculty who were going on a recruitment visit. She felt more confident speaking to the high school group than to a group of faculty. Hopefully, that was the first step to enhancing her success at public speaking. Another scholar was dragging his feet at setting up the high school visit. He had no real experience at taking the lead and being proactive at contacting people. The assignment forced him out of his comfort zone into an opportunity for growth.

Conclusion

The impact on education includes: (a) Enhancement of the technical and educational backgrounds of minority undergraduate students by offering collaborative research activities; (b) Increasing the number of well-prepared minority undergraduate students to enter the graduate school by providing vital information and necessary training for their admission to and success in the graduate school; (c) Promoting inter-cultural participation among non-minority and minority students and faculty members; (d) Assisting minority students in their development towards possible employment in high level engineering/science jobs; (e) Enhancing the minority students' computer skills by integrating the acquired knowledge in microfabrication and heat transfer into computer driven projects; and, (f) Providing tutoring or teacher assistant service to high schools by minority undergraduate and graduate students during the academic year.

Benefits

All of the students are benefiting from the collaborative project. They have access to state-of-the-art facilities at both Universities and through internships at CAMD. They have had the opportunity to network with professors and professionals from other organizations. The students working on the team recognize that they are being trained in more than the technical aspects of the research and they express gratitude for the chance to act in more of a leadership role as they supervise and guide their counterparts.

All of the students who have completed visits described how excited the high-school students were to have college students to talk to them because many of them said none had ever visited them at school before. Many were unaware of the research capabilities available at Southern University and they were amazed at the technology that was presented to them. Some said that they would consider attending Southern University more seriously since being visited.

Future Plans

In the future, the educational leader of the team will develop a survey or other instrument to determine how well the mentoring and outreach is working to meet the project's educational goals. While the team is certain that these activities are providing a benefit to the participants, it will be useful to measure how the visits are impacting recruitment, retention and attitudes toward engineering as well as the enhanced professional development of the undergraduate and graduate mentors.

Acknowledgements

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