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## **AC 2011-1667: INTERNATIONAL RESEARCH EXPERIENCE FOR ENGINEERING STUDENTS IN CHINA IN THE AREA OF FUEL CELLS**

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# **International Research Experience for Engineering Students in China in the area of Fuel Cells**

## **Abstract**

The department of mechanical engineering at Oakland University was awarded by the National Science Foundation a three year grant entitled “International Research Experience for Students(IRES): Collaborative Research Activities with China on Fluid and Thermal Transport in Fuel Cells.” The objective of the proposed IRES site is to annually provide five U.S. engineering students (four undergraduates and one graduate) with the unique opportunity to work on fuel cell collaborative research between Oakland University (OU) and Beijing Jiaotong University (BJTU) in Beijing, China. In the past summer, a total of 6 students have taken part in the IRES program. These students stayed in Beijing Jiaotong University for 8 weeks and worked on three different projects related to fuel cells. This paper will focus on the organization of this program including pre-departure preparation, on-site orientation, on-site activities and post-program assessment. Also, the lessons learned from running this type of program will be summarized. Some suggestions to keep the sustainability of the program will be also provided.

## **Introduction**

The globalization of science, engineering and manufacturing is very important in re-shaping the current US economy. Much has been made in the literature about the cultural differences between the U.S., European, Asian and other educational systems [1-9]. Many foreign scientists come to U.S. institutions to conduct research and make use of state-of-the-art laboratory facilities. The number of foreign students at U.S. universities is significantly higher than that of U.S. students at foreign universities. However, if the U.S. is to remain competitive in a global economy, it is important that future engineering leaders and researchers be given the opportunity to experience firsthand what it is like to work in a foreign research environment and to establish a network of contacts that could lead to future international collaborations.

To address these issues, the department of mechanical engineering at Oakland University applied for the National Science Foundation grant entitled “International Research Experience for Students(IRES): Collaborative Research Activities with China on Fluid and Thermal Transport in Fuel Cells.” The grant was funded and the NSF award number is #0853572. This is a three year program starting on Oct 1, 2009.

The objective of the proposed IRES site is to annually provide five U.S. engineering students (four undergraduates and one graduate) with the unique opportunity to work on fuel cell collaborative research between Oakland University (OU) and Beijing Jiaotong University (BJTU) in Beijing, China. This program is similar to the NSF REU program, but provides an international research experience to students. Key features of this international research experience include:

- 8 weeks of paid summer research for 5 U.S. engineering students at OU and BJTU on topics considered to be of critical importance to fuel cell technology development. The program took place from May 17, 2010-July 12<sup>th</sup>, 2010.
- A strong commitment from the BJTU collaborators to provide the students with a fruitful and challenging multidisciplinary research and international experience and access to facilities that they wouldn't otherwise have access to at OU.
- A faculty team with experience in the area of fuel cell technology and organization of exchange programs to China.
- A number of activities meant to prepare and expose students to Chinese culture, enhance their confidence levels, improve their communication skills and provide them with the tools and motivation necessary to succeed in their professional or graduate endeavors.

This paper will focus on the organization of this program including pre-departure preparation, on-site orientation, on-site activities and post-program assessment. Some suggestions to keep the sustainability of the program will be also provided.

## **Application and Recruiting**

***NSF IRES Participant Recruiting:*** (Oct 04, 2009- January 04, 2010) The program ran for the first time for eight weeks in the summer of 2010, between May 17 and July 09. The NSF IRES flyer was prepared once the award was confirmed by the OU grant office in Oct 2010. The IRES flyers were sent out through the ASME ME departmental chair email list, the professional society advisors of SWE, SAE, ASME, SME and IHAE and individual faculty members at various institutions. The program was also promoted in the classroom by engineering professors at OU. A website [10] was created to advertise this program and an on-line application system was created for the convenience of application. The application deadline was January 04, 2010. This deadline is much earlier than most of other summer REU or internship programs. The reason is that extra time is needed to prepare documents for international travel and logistics and accommodation arrangement.

***NSF IRES Participant Selection:*** January 04, 2010- Feb 28<sup>th</sup>, 2010: We received more than 30 outstanding applications (the average GPA was 3.7) from 25 different universities across the US including top schools such as Princeton University and Northwestern University, and 7 of these applications were from female students. Of all the recruiting efforts used, the most effective in the first year were the messages sent to the ASME ME departmental chair e-mail list. The student eligibility requirements were set as follows:

- Undergraduate engineering students entering junior or senior year (graduating after December 2010) or graduate engineering students (graduating after December 2010)
- Minimum GPA 3.0 (undergraduate) and 3.25 (Graduate)
- Undergraduate students must have completed or currently be enrolled in a junior level fluid mechanics or heat transfer course
- Must be a U.S. citizen or permanent resident

On January 14<sup>th</sup>, the IRES committee reviewed each application very carefully and selected the top five applicants as IRES participants. Five students were on the waiting list. Our NSF grant

provided funding for five students. However, given the success of the application request and the number of qualified applicants, additional funding was sought and obtained from Oakland University's Office of the Provost and Vice President for Academic Affairs to support one additional OU student, bringing the total number of student participants in the first year to six. The program director made calls to each candidate to confirm their interest in the program. An official offer letter was sent out to the candidates in the end of January, and all the students had to return the signed letter to confirm their participation by Feb 10, 2010. An email was then sent to notify those applicants who were not selected for the program. A brief profile of the 2010 NSF IRES Participants is shown in Table 1.

**Table 1** – Gender, affiliation, major, class level and ethnicity of 2010 NSF IRES participants

<b>Gender</b>	<b>Class</b>	<b>Ethnicity</b>	<b>GPA</b>	<b>Affiliation</b>
F	Jr.	Caucasian	3.81	The George Washington Univ.
M	Jr.	Caucasian	3.94	Northwestern Univ.
M	Jr.	Caucasian	3.8	State Univ. of New York at Buffalo
F	Jr.	Asian /American	3.93	New York Univ.
M*	Grad.	Caucasian	3.6	Oakland Univ.
M	Grad.	Caucasian	3.84	Michigan Technological Univ.

\*This student was supported by Oakland University Provost Office, School of Engineering and Computer Science and the Department of Mechanical Engineering.

The GPAs of the students varied between 3.6 and 3.94. Two out of the five students funded through the NSF were female. A summary of the students' profile regarding their experience prior to this program is as follows:

- None of the students had prior research experience in China; only one student travelled to China for a short period of time with family member.
- One student never had any research or internship experience, one student had experience as a research assistant in the lab, and the other 4 students had internship experience.

## **Program Structure and Activities**

**Pre-Departure Logistics:** Different from the regular NSF REU program, this NSF IRES program requires a significant amount of work to prepare the participants to study abroad successfully. Instead of having an on-site orientation at Oakland University before departure, we met the students at Beijing Jiaotong University directly. There are several reasons for doing this:

- 1) The semester of BJTU ends by Mid July. Therefore, our program has to finish before the BJTU final exam week. The US schools ends their semesters on different dates. It is not easy to find a common week in early May for students to gather in OU before leaving for China. May 15 was the earliest date that all the IRES participants were available.

2) Since this is an international program, all participants prefer to stay in China longer if possible. This is reflected in the end of program survey. For example, one student said “I think that the stipends could be less, and the program could last 10 weeks. I would definitely accept more time in China for less money.”

Therefore, a significant amount of efforts was required before the departure to overcome student’s fear, doubt or concern of studying in China. These efforts include:

- 1) **Booking Airticket:** To secure a seat and a better price, the air ticket was reserved two months before departure. The program director coordinated with each NSF IRES participant to confirm their departure dates, departure airports, returning dates and returning airports. Since these participants finished their school on different dates, they have different departure dates. The arrival dates in China were scheduled no more than 1 day later than the program starting date.
- 2) **Travel Documents:** All participants must have a passport and a visa stamp in order to travel to China. It took about one month and a half to collect passports, apply for visa, and return the stamped passports to students. This was done during the month of March and early April.
- 3) **Employment Package:** Since the NSF participants were not physically present at Oakland University, the program director contacted the human resource department at Oakland University to initiate the hiring process. An employment package was sent to students in late March by the Human resource department at Oakland University, and all students returned their paper work on time. Some students did make some mistakes or did not return supporting documents. However, overall this was a very efficient process. We recommend continuing this process in next year’s program.
- 4) **Other Documents:** To ensure students’ safety in China, we asked each participant to provide emergency contact information and their current medical insurance form. The program also purchased travel insurance [11] for each student to cover their stay in China. Each participant also was also required to sign a release and assumption of risk form.
- 5) **Conference Call:** Two weeks before the departure, the program director made a conference call to all the NSF IRES participants. This served as an informal off-site program orientation. A handbook prepared by the program director was sent to students. From talking to the students, they all felt that the handbook helped them significantly in preparing for this trip. They felt much more comfortable after reading the handbook. Students also suggested adding more information to the handbook such as recommending students bring their cellphones to China. Based on students’ comments, this handbook will be improved for next year’s program.

***On-Site Research and Teaching Activities:*** Numerous activities were conducted for the program. Each participant was required to take 24 hours of Chinese language instruction. This training class was scheduled in the morning between 8:30am and 9:30am from Monday-Thursday for six weeks. The Chinese language training turned out to be one of best experiences students had in China. This can be seen from students’ comments:

“The Chinese language class was very good and our teacher was very helpful. I wish I would have studied more Chinese before starting the program. “

“The language class was fantastic!! Try to get Sheryl again for next year's program”

This research focus of this program is fuel cell related projects. Based on the existing infrastructure at Beijing Jiaotong University, four different projects were selected as the potential projects for the NSF IRES group. The PI presented each project to the IRES group, including the project objective, required knowledge and skill, and some related references. Each student was given one day to understand the project, and to indicate their level of interest in each project. Project assignment involved taking the students' preferences in mind, as well as trying to pair up appropriate skills and backgrounds to each project. Luckily, all students got their first choice and were pleased with the project assignment process. Six IRES students were divided into three groups to conduct the fuel cell related project. Each group was assigned to work with one Chinese student at BJTU.

Listed below is a brief description of each project which was conducted at BJTU:

*1) Development of a Method for Optical Measurement of Water Droplet Formation in the Cathode Flow Channel of a PEM Fuel Cell*

A method was investigated to optically measure the relative size and frequency of water droplet formation in the gas flow channels of a polymer exchange membrane fuel cell. The method was derived from optical sensors developed from basic principles of phosphor thermometry for remotely measuring surface temperature, but was modified to simultaneously detect water formation based on signal attenuation. Both a mathematical model and experimental measurements were developed and performed in order to correlate signal data to droplet size and shape. It was found that no strong correlation between theoretical and experimental results existed due to many possible factors. The work is ongoing and new methods of water droplet characterization are still being investigated.

*2) Correlation of Breakthrough Pressure to GDL Thickness in PEM Fuel Cells*

This project sought to determine the correlation between the water pressure required to break through the GDL (breakthrough pressure) and the thickness of the GDL used in a PEM fuel cell. A transparent testing apparatus was designed to increase water pressure below the GDL until the water visibly broke through the surface of the GDL. The breakthrough pressure was found to be initially high for a given sample, and subsequent trials broke through at lower pressures. The initial high breakthrough pressures were correlated with GDL thickness and a linear relationship was found.

*3) Optimization of Flow Distribution in Fuel Cell Channel Design*

This project sought to optimize the flow channel design on bipolar plates of proton exchange membrane fuel cells. Comsol is utilized to model the flow field constrained by the Navier-Stokes and Brinkman's Equations. The quality of the flow field was measured by the variance of

the pressure drops between the inlet and outlet channels. The results of each Comsol simulation are passed into Matlab, which via an iterative optimization procedure modifies the gate heights and passes the new geometry back into Comsol. This process repeats itself until the variance is within some specified tolerance. An analytical approximation is also generated that will directly solve for gate heights. The model assumes constant pressure drop between inlet and outlet channels, volumetric flow is proportional to channel length and half the flow from any given inlet channel will diffuse to the outlet channels on either side. This served as a comparison with the numerical results. This project results in a conference publication [12].

In addition to regular group meetings with faculty mentors every Friday, each group made a mid-term presentation and a final project presentation. A written report was also submitted by each group. These written reports included two parts: one was project related and the other was life experience in China.

Other activities were also arranged to improve students' understanding of fuel cell technology and enhance their research ability. These activities include:

- 1) *Visited Green Energy Company in Beijing*: This is one of the largest fuel cell manufacturers in China.
- 2) *Visited Research Laboratories at University of Science and Technology Beijing and Shanghai Jiaotong University*
- 3) *Gave a seminar on life in US universities at Beijing Aeronautic and Astronautic University.*
- 4) *Presented in conference and research symposium in China*: Two IRES participants presented their findings in two different events: one is the Competition for Research Presentation by Young Investigators at North China Electric Power University and the other is the Graduate Student Symposium at Tianjin University of Finance and Economics.
- 5) *Attended research seminars*: The IRES students attended three technical seminars given by the faculty mentors as follows:
  - a) Introduction to Fuel Cells
  - b) Introduction to Heat Pipes
  - c) How to conduct Research

Students benefited from most of field trips except for the one to Tianjing University. The reason was that the seminar was given in Chinese. We don't plan to attend this type of research symposium in the future unless the speaker presents in English.

## **Assessment**

The primary goal of this IRES program is to engage participants in rewarding international research experiences that excite and motivate them to pursue careers in scientific and engineering research on an international scale and to be able to collaborate on complex engineering and research projects with colleagues and collaborators across the world. Although it is still early to gauge the long term effects of this program on the student participants, a few things can be summarized from the pre-program application and post program surveys that the student participants have completed.

- 1) In the application essay, two students out of four undergraduate students indicated plans to go to graduate school after graduation. By the post-IRES survey, that number had increased to three, and the fourth student mentioned that he would like to work first and then go to graduate school. Three of them have indicated that they will prepare to take the GRE exam during the summer after the NSF IRES program.
- 2) On a scale of 1 to 5, with 1 being poor and 5 being excellent, students rated their overall IRES experience as a 4.8 and all indicated that they would recommend the program to their friends. Most of the activities received ratings above a 4.0.
- 3) Students rated the following experience below a 4.0:
  - a. The research facility at the host Chinese school;
  - b. Some field trips, for example the field trip to Tianjin University.

These low ratings, however, are expected. The research laboratory at Beijing Jiaotong University is quite different from the US schools. Tools and equipment are not as easily accessible as in US universities. Most parts designed by students are machined by a contractor. It thus usually takes long time. However, this is the situation for most of universities in China. This is also part of learning experience in China. Here are some students' comments regarding the research environment and research facilities "*As far as environment goes, BJTU was a good place to live. The labs weren't ideal as far as available tools, but it was manageable*" and "*The general disorganization was difficult to deal with. However, the status of the lab required us to be resourceful, which was a good experience anyways.*" To solve this problem, we plan to design projects in the future which are more closely supported by the existing infrastructure at BJTU. Meanwhile, the Chinese mentor has also agreed to upgrade the laboratory.

We arranged for our students to visit several university laboratories and also arranged our students to attend a few research seminars. It seems that our students enjoyed the laboratory visits. However, they did not learn much from the seminar since most of seminars were given in Chinese. In the future, we will either ask the host school to organize the seminar in English or we won't participant in the seminar.

## Conclusions

Setting up and running an IRES program is a very time consuming project. It requires a group of dedicated faculty members from both US and China who are willing to work hard to create a comfortable research environment to students for an exciting, manageable and innovative project. Although, as would be expected in the first year, we ran into some glitches and can do a number of things to improve the program, all of the people involved in the program feel that this was a successful program and look forward to the next few summers. Comments such as the ones listed below make it all worth it!

"Overall I think it was a good experience. While the resources at BJTU are very limited, it does give students the opportunity to learn something about fuel cells. I think the best experience from the program is just learning more about the Chinese



culture especially when it comes to science and engineering. I like to think we taught the Chinese students that we worked with a lot too.”

“ it was a great research and cultural experience that you can learn a lot from”

“ I found it a valuable experience both culturally and academically and overall enjoyed the atmosphere.”

“Definitely because it was an amazing experience that I'm going to remember forever. Plus, with all of the benefits, it is a great deal.”

“This program opened my eyes to life in Beijing and spending time with Chinese students was a wonderful experience. I have learned how to conduct research and improved my academic skills. For me, the best times of this trip have been when meeting and talking with Chinese people. It is difficult in this program to achieve all your research goals just because of all the exciting things going on, but it one of the best experiences of your life. Everyone has been so welcoming.”

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