AC 2007-1140: A CRCD COURSE SEQUENCE – TECHNOLOGY SERVING HUMANITY APPLICATIONS

Goodarz Ahmadi, Clarkson University

John McLaughlin, Clarkson University
Professor of Chemical and Biomolecular Engineering at Clarkson University

Stephen Doheny-Farina, Clarkson University

A CRCD Course Sequence – Technology Serving Humanity Applications

Goodarz Ahmadi,[1] John McLaughlin[1] and Stephen Doheny-Farina[2]

[1] Wallace H. Coulter School of Engineering
[2] School of Art and Science
Clarkson University, Potsdam, NY, 13699-5700

Abstract

Understanding particle transport, deposition and removal are of crucial importance to many environmental and biological processes. In addition, many technologies that are critical for the competitiveness of the US microelectronic, imaging and pharmaceutical industries require an engineering work force that are competent in various aspect of particulate processes. The primary objective of this NSF supported combined research and curriculum development (CRCD) project is to make the results of new important research findings in this critical area available to seniors and first year graduate students in engineering through developing and offering of specialized courses. In this CRCD project a series of courses on particle transport, deposition and removal and re-entrainment was developed. The course materials are available on the web the course was taught it at two campuses simultaneously. The CRCD courses are composed of four modules:

- Fundamental of particle transport, dispersion, deposition and removal.
- Computational modeling of particle transport, deposition and removal.
- Experimental study of particle transport, deposition and removal.
- Industrial and environmental applications of particle transport, deposition and removal.

In this paper, the course development project is outlined and various modules of the course are reviewed. Particular attention is given to the new application modules of the course in connection with particle transport, deposition and removal in biological and environmental applications. In this regard the connection of the course with the motto of Coulter School of Engineering on "Technology Serving Humanity" is emphasized. The results of course web evaluation is also presented and discussed.

Introduction

Particle transport, deposition and removal occur in numerous environmental and biological processes. In addition, many technologies that are critical for the competitiveness of the US microelectronic, imaging and pharmaceutical industries involve extensive usage of particle transport, deposition and removal. In the recent decade, there has been significant research finding on particulate transport, deposition and removal processes. The primary objective of this combined research and curriculum development project is to make the fruits of these new important research findings available to seniors and first year graduate students in engineering through developing and offering of sequence of specialized courses. An extensive web for the course materials was also developed and posted for open usage. The courses were taught simultaneously at Clarkson University and Syracuse University as part of the effort of Center of Excellent for Environment and Energy.

In the present study, the basic modules of the course are described and the application modules of the course in connection with environmental and biological processes are discussed. The results of usability of the course web are also presented.

Course Modules

The CRCD course sequence is composed of four basic modules. These are:

- Fundamental of particle transport, dispersion, deposition and removal.
- Computational modeling of particle transport, deposition and removal.
- Experimental study of particle transport, deposition and removal.
- Industrial, environmental and biological applications of particle transport, deposition and removal.

The lead web page of the first course ME 437 is shown in Figure 1. The lecture notes and the calculations models are uploaded into the course web and are available in both pdf form as well as html format.

Module I, Fundamentals

In Module I the descriptions of fundamentals of aerosols including hydrodynamic forces (drag, lift), and adhesion forces were described. The nature of particle adhesion and removal was also discussed. This module also contains the description of particle interaction with laminar flow, Brownian motion process, and particle deposition by diffusion, interception and impaction.

The sections on interaction of particles with turbulence and turbulent deposition are normally taught in the second course. Computational modeling of turbulent flows was discussed, and classical models of turbulent deposition were described. In addition the process of aerosol charging and transport under the action of electrical forces and turbulence were discussed.

We have added a number of computational modules to make the course presentations of the materials more interactive. The plan is to have sufficient number of calculation modules for the student to experiment with. As a result the student will develop a physical understanding of some of the more complex concepts.

Module II, Computer Simulations

We refined and developed several computer modules that were incorporated into the course sequence. One class of examples was concerned with exploring the flow and particle transport in a variety of obstructed ducts. Fortran simulation programs that were developed earlier were converted to JAVA. These programs were incorporated in the modules dealing with the motion of aerosol particles in the obstructed duct flows. The students will be able to interactively use the programs to explore the effects of various forces (gravity, drag, lift, Brownian), materials properties (particle density), and the flow geometry on the motion and deposition of particles.

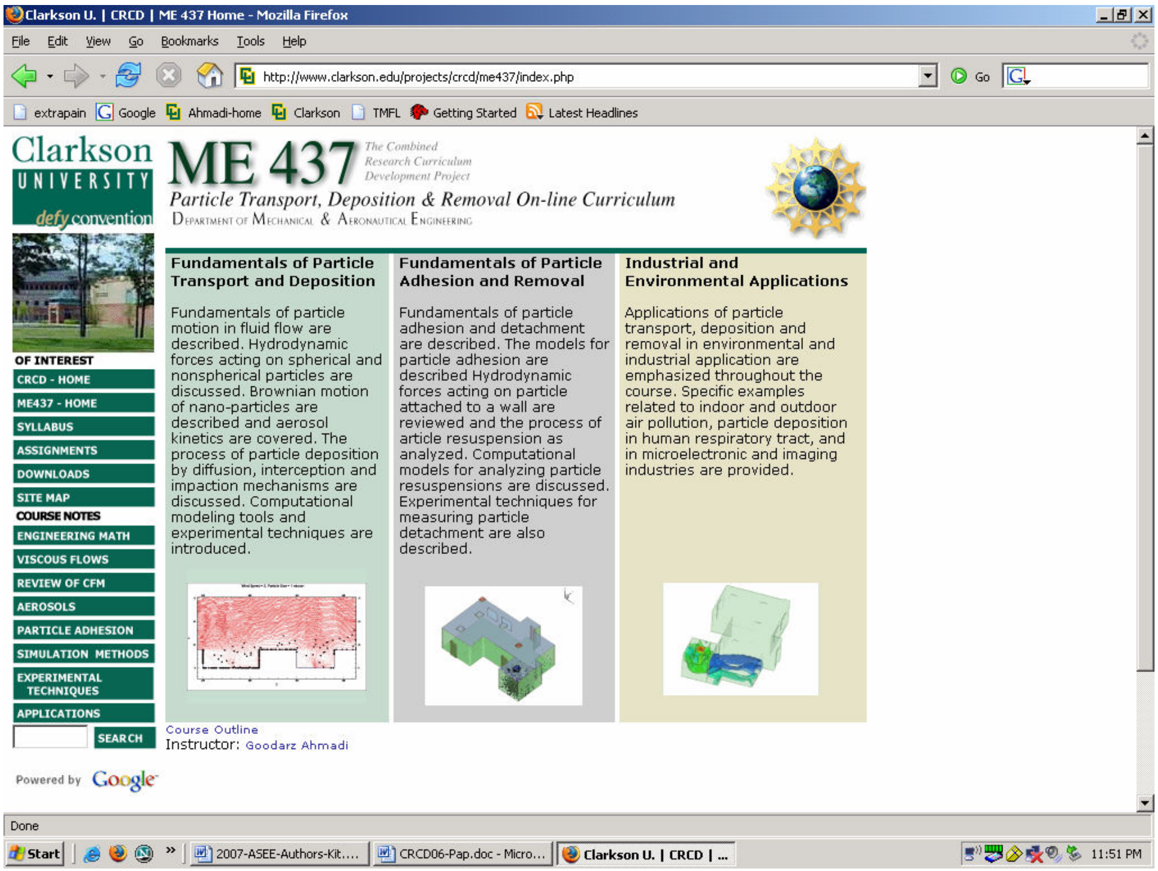


Figure 1. Leading web page of the first CRCD course.

A module was developed for illustrating Brownian particle motion in cross flows. The flow field in this module is a parabolic velocity profile between two parallel plates. The particle equation of motion includes Brownian motion, drag, lift, and gravity. Figure 2 shows the user interface for this module. Here, particles are injected from a nozzle in the middle of the channel. The dispersion of the Brownian particles can be seen. Student can select values of the particle diameter and density, the number of particles, the centerline fluid velocity, fluid density, and the fluid viscosity. The program then computes as many particle trajectories that the user asks for. The program also computes the variance of the particle trajectories. In the course the students use these modules to get a better understanding of the processes involved and the parameters that are important. When the students do their course projects that involve more practical applications of particle transport, deposition and removal, they can check their models by testing the limiting conditions and compare the results with the posted module.

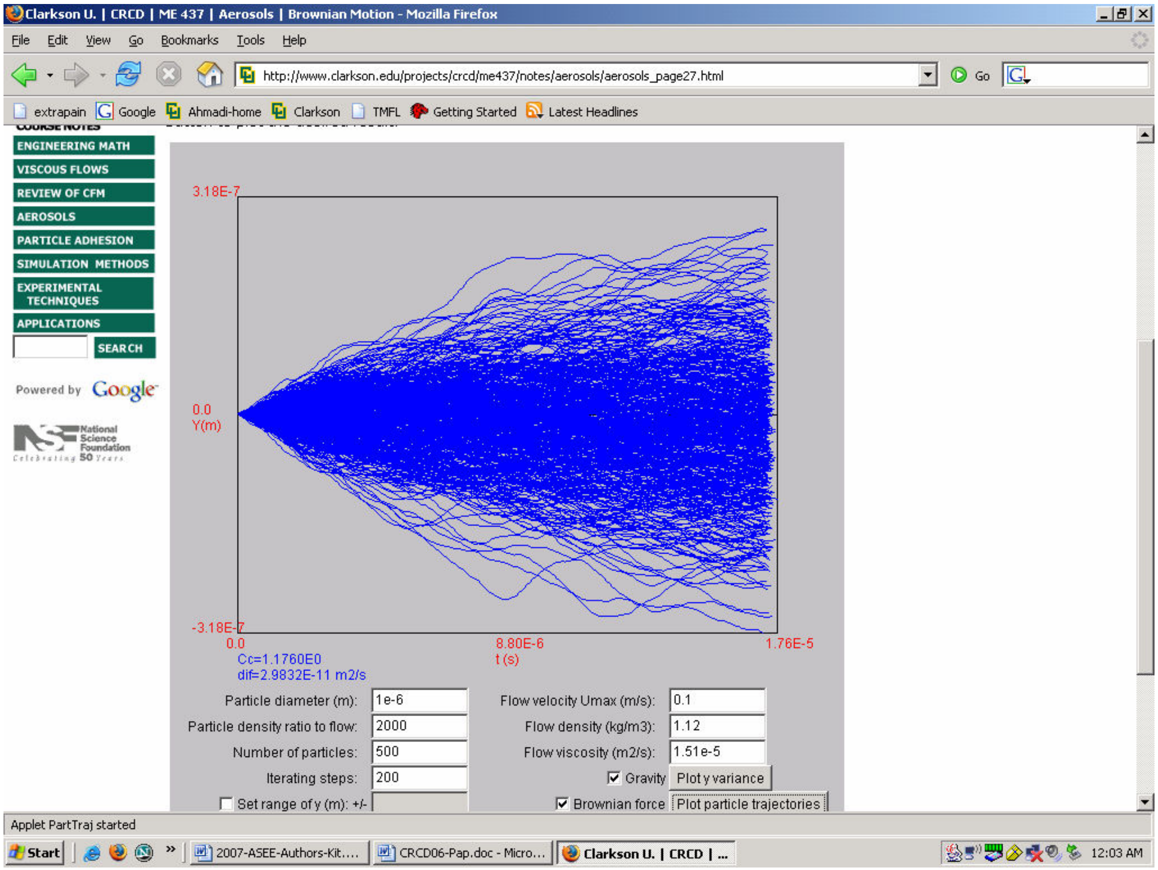


Figure 2. User interface for the module for Brownian particle motions in cross flows.

Module III, Experimental

The course sequence includes several experimental modules. One main experiment is the measurement in the aerosol wind tunnel with the use of Particle Image Velocimeter (PIV). The aerosol wind tunnel is located in the Turbulence and Multiphase Flow Laboratory at Clarkson University. The laser used was a 120mJ Nd:YaG laser with a 20° adjustable width sheet generator. In this experiment, the sheet width was 0.5 mm. The digital camera that was used was a Kodak ES1.0 MegaPlus camera. The camera had a pixel range of 1008x1008. The pixel size was 25 micrometers and the interframe delay between pictures was 12 microseconds. A picture of the experimental setup is show in Figure 3. A sample PIV measurement of the velocity field behind a step is shown in Figure 4. In addition, there are experimental setup for studying particle adhesion and detachment in a small wind tunnel. The student test the value of the critical velocity needed to detach particles of different sizes and different materials. The setup allows spreading particles on a flat surface and expose it various airflow velocities. The test section is being observed under a microscope and photographs of the particles resting on the surface are taken with a digital camera for different air speeds. The images are analyzed with and software and the number of particles of different sizes are evaluated and used to estimating the critical velocities need to detach the particles.

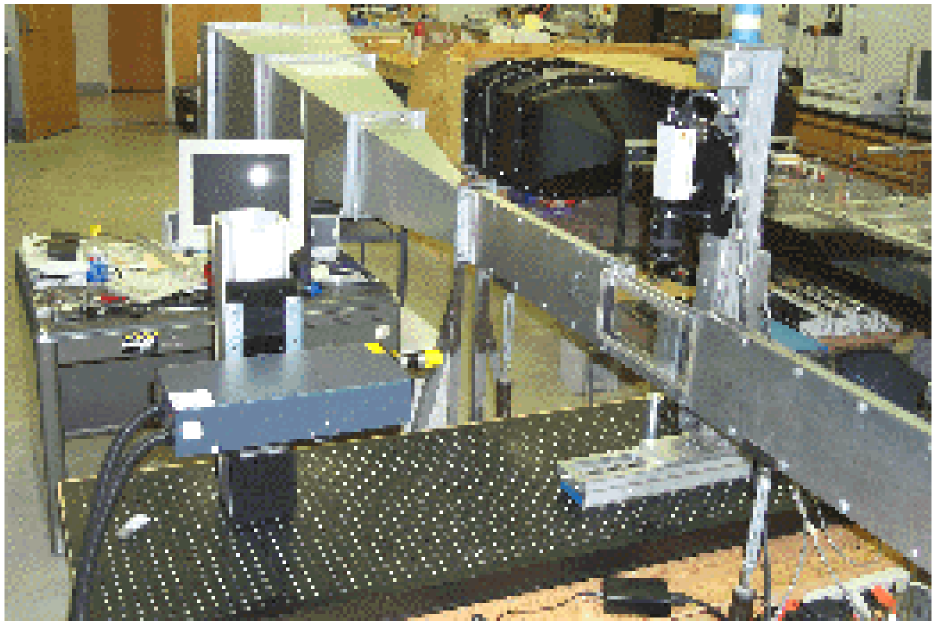


Figure 3. A picture of the aerosol wind tunnel.

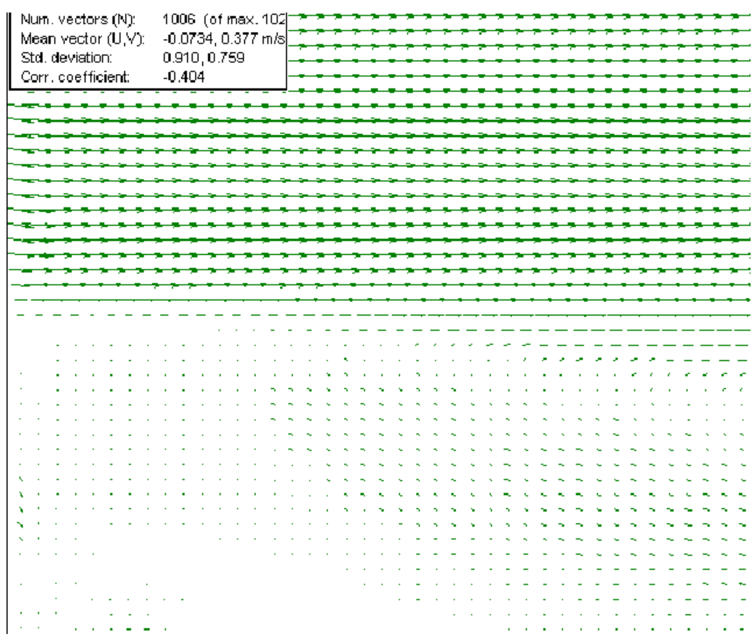


Figure 4. Sample PIV measurement behind a step in the aerosol wind tunnel.

For student on the other campuses taking the course, the experimental data were posted on the web for their usage. We are exploring the potential for operating some of the experimental equipment remotely. That will be helpful for the students elsewhere who are interest to take the course.

Module IV, Technology Serving Humanity Applications

The applications module of the course is concerns with a number of examples from air pollutions to xerography. Particular attention has been given to environmental and biological application that connects the course to the motto of the School of Engineering, Technology Serving Humanity. Figure 5 shows the photo of the Peace Bridge area in the south west Buffalo, NY. Figure 6 shows a sample computational result for the dispersion of particulate emission form the traffic on the Peace Bridge.

Figure 5. A picture of Peace Bridge area and city of Buffalo.

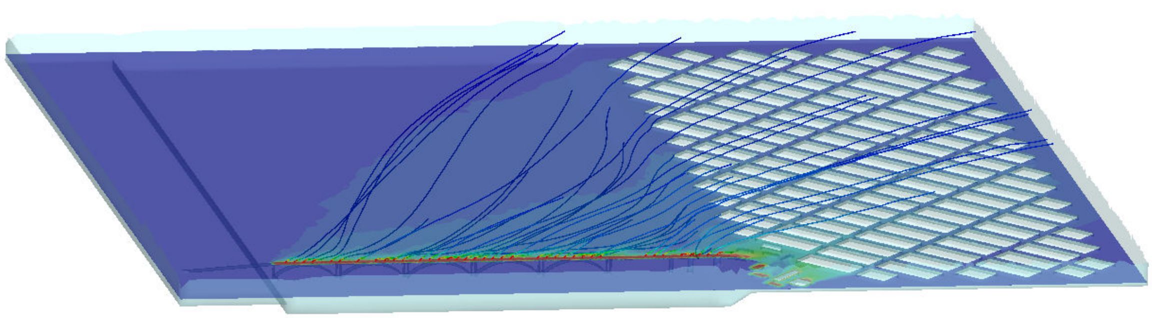


Figure 6. Sample computational result for pollutant dispersion form Peace Bridge traffics.

Figure 7 shows sample computational results the airflow in the upper airway of an anonymous human male. Here the velocity magnitude contours at several sections along and across the airway are shown. The corresponding sample particle trajectories are shown in Figure 8.

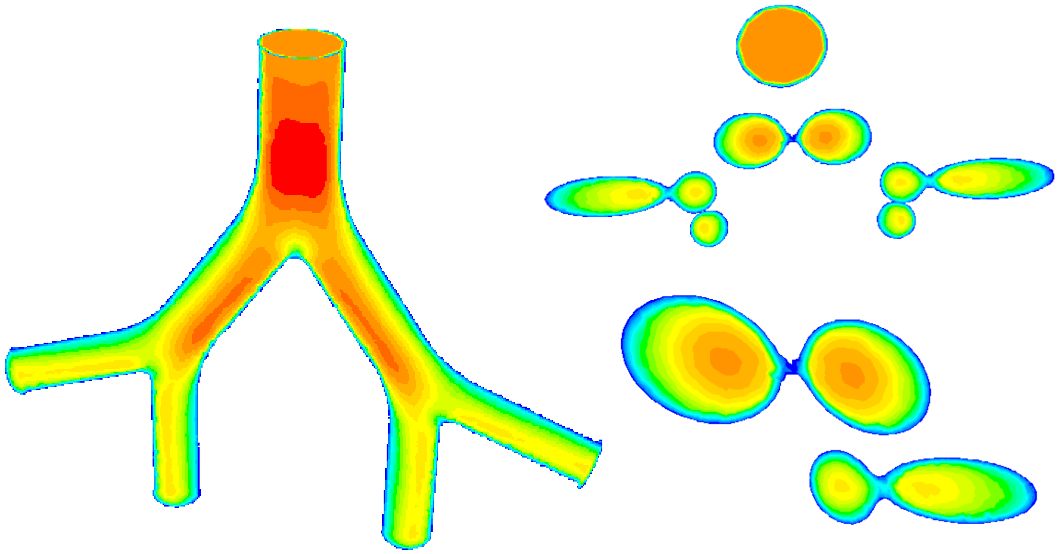


Figure 7. Sample velocity magnitude contours at several sections of the upper airways of anonymous human male.

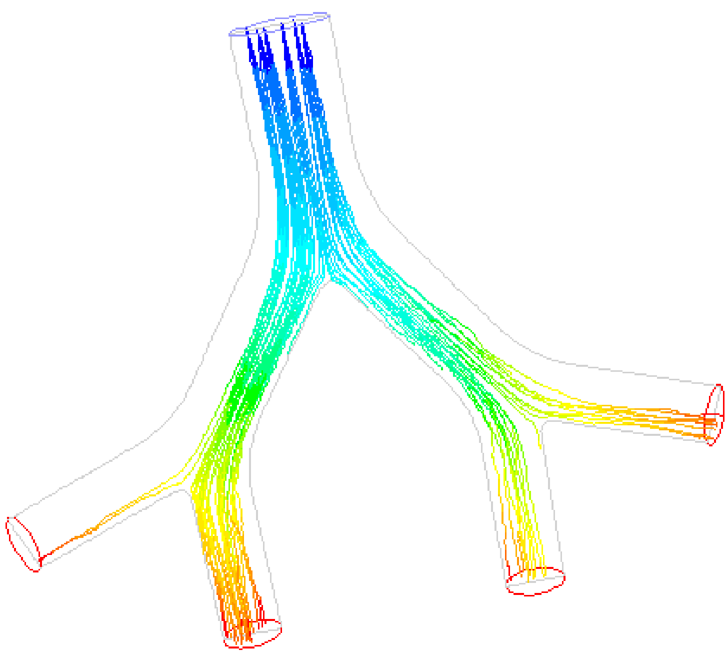
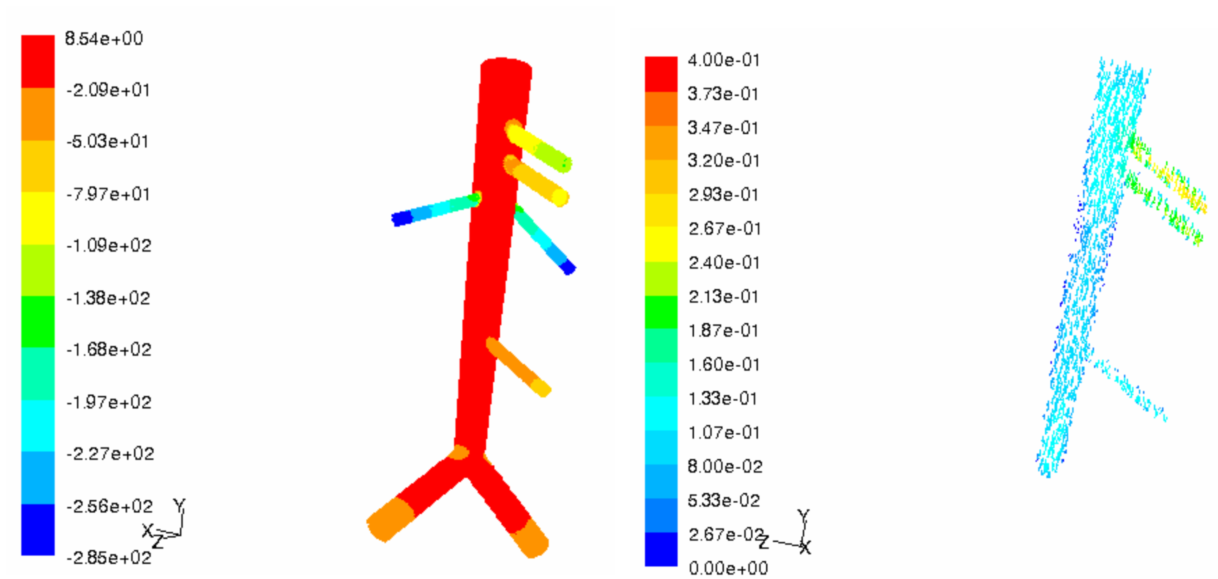


Figure 8. Sample particle trajectories in the upper airways.

Blood flow through a 3-D model of a human abdominal aorta was simulated and results are shown in Figure 9. Both Newtonian and non-Newtonian models for blood flow were used and the results are and compared. Figure 9a shows the pressure contours at walls of the arteries in the human abdominal aorta. It is seen that there is a significant pressure drop form the main artery to the connecting ones. Figure 9b shows the velocity vector field at some sections of the domain.



a) Pressure Contours **b) Velocity Vector Field**

Figure 8. Sample simulations of blood flow in the human abdominal aorta.

Course Web Effectiveness

The effectiveness of the course (ME 437/537) website was assessed in two ways:

1. Usability tests were conducted on an early version of the site and conducted again on a revised version of the site. In both tests, participants were given tasks to find course material and use the calculation model available on the site. The purpose of these tests was to determine how efficiently the participants could complete each task.

2. A survey questionnaire was administered to students enrolled in the courses designed to assess the students' satisfaction with the website.

Usability Tests

The Usability Testing Lab in the Eastman Kodak Center for Excellence in Communication at Clarkson University was set up to record users testing out the website. Participating in the first test on the early version of the website were twelve student volunteers: six Mechanical Engineering majors and six Information Technology majors. Information from these tests were communicated to the website designers. A year later after the website had been redesigned a second usability test was conducted with two Mechanical Engineering majors and three Information Technology majors

For both test sessions a list of twelve tasks was devised that would cover a variety of possible uses of the website. All tasks required the students to search the site for courserelated information. One task asked the students to do a calculation using the calculation model currently embedded into the site.

The results indicate that the participants using the revised site completed the tasks more efficiently.

<u>Original Site</u>
Average number of clicks, searches, scrolls to complete each task per user: **3.70**
<u>Revised Site</u>
Average number of clicks, searches, scrolls to complete each task per user: **2.56**

<u>Original Site</u>
Average number of failed or incomplete completions of the task per user: **1.41**
<u>Revised Site</u>
Average number of failed or incomplete completions of the task per user: **0.60**

Survey Questionnaire
Twenty-two students completed a questionnaire upon completing the course in which the students could use the website to assist their learning. Overall, these students found the website useful for their needs:

1. The website was used to access information and employ calculation models:
- 77% used the website to read the course syllabus
- 86% used the website to read homework assignments
- 77% used the website to download course notes
- 54% used one or more of the calculation models

2. Students found the availability of course notes to be useful:
- 86% found the course notes to be easy to moderately easy to find.
- 96% found the course notes helpful to moderately helpful to their coursework.
- 86% found the course notes to be easy to moderately easy to understand.

3. Students found the calculation models to be useful:
- 81% found the calculation models to be helpful to moderately helpful.
- 81% found the calculation models to be easy to moderately easy to use.

4. Overall, 86% found the website to be very to moderately helpful to their coursework.

Conclusions

The development of a sequence of web-based courses on particle transport, deposition and removal was described. Different modules of the course are outline. The suitability of the course web in helping the student learning was assessed. The results showed that the availability of the course material and computational module on the web was very helpful to student learning, and students at multiple campuses could take the course simultaneously.

Since these courses are commonly taught at other universities, we plan to offer the course to other campuses. This will increase the impact of the course sequence in engineering education. At the present time the course web is open and many students and interested individuals visit the site. Currently, the main site had more that 20,000 visitors. Each of the courses had more than 13,000 visitors.

References

http://www.clarkson.edu/projects/crcd/