Multi-Media Based Laboratory Modules in Particle Technology for the Undergraduate Core Laboratory Curriculum

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Abstract: Particle Technology has generally been neglected in the engineering curriculum in the USA, yet it is a very important interdisciplinary field vital to US economy. In order to make undergraduate engineering students more familiar with powder and bulk solids processing, we intend to bring some of the results from the recently completed NSF Combined Research and Curriculum Development (CRCD) project at NJIT into our undergraduate core laboratory courses in Mechanical and Chemical Engineering. To accomplish this, we are employing a unique approach that combines active participation of industrial partners in the selection, design, and delivery of the instructional modules, with current computer based technologies such as multimedia and the world-wide-web (WWW). The use of the Internet allows for more efficient delivery of instructional material and also rapid incorporation of new material. In addition, it allows for compiling a large amount of multimedia based information, available from our own research experiences and collaborations, through content sensitive links, and thus creates a vehicle for learner-oriented pedagogy. It also makes the task of dissemination much easier. In this paper, we describe our preliminary work that includes involvement of several faculty members, graduate and undergraduate students, and industrial partners. The final version of this courseware is expected to be available for dissemination by the end of 2001.

Keywords: CD-ROM, hands-on laboratory, multimedia, partnership, particle technology,

1. Introduction

This paper describes an ongoing project, supported by a grant from the National Science Foundation, for development of experimental modules in particle technology to be incorporated into the undergraduate engineering curriculum at New Jersey Institute of Technology. This will be accomplished trough a unique approach combining active participation of industrial partners in selection, design, and delivery of the instructional modules, with current computer based technologies such as multimedia and the world-wide-web. The experimental modules considered for adoption are derived form a previous NSF funded CRCD (Combined Research and Curriculum Development) grant [1-4]. As described in the next section, particle technology is an important interdisciplinary field vital to the US economy, yet generally neglected in the engineering curriculum in the USA. Thus we expect this project to have a large impact on undergraduate engineering education in the area of particle technology.

1.1 The importance of education in particle technology

Particle technology is concerned with the characterization, production, modification, flow, handling and utilization of granular solids or powders, both dry and in slurries. It spans a host of industries including chemical, agricultural, food products, pharmaceuticals, ceramics, mineral processing, advanced materials, munitions, aerospace, energy and pollution control. The subject matter in particle technology is highly inter-disciplinary in nature.

Despite its great importance, until recently, particle technology had virtually no presence in the undergraduate engineering curriculum and very little presence in the graduate curriculum in the United States. Fortunately, during the past few years, there have been several new educational activities initiated in this field. Amongst these, a team of five interdisciplinary faculty members at NJIT (Profs. Dave, Fischer, Luke, Pfeffer and Rosato), has developed a three course concentration in Particle Technology across the engineering curriculum with support from the National Science Foundation (NSF). Recently, the Particle Technology Forum (PTF) of the American Institute of Chemical Engineers (AIChE) has also been involved in encouraging chemical engineering educators to incorporate particle technology into the undergraduate curriculum [5]. At the 1997 ASEE Summer School for Chemical Engineering [6] held in August 1997, an entire session (two days) was devoted to educational activities in particle technology and these were later highlighted in the Spring 1998 issue of *Chemical Engineering Education*, [3, 6-8]. The industrial perspective and industrial participation is described in [9].

1.2 Combined Research and Curriculum Development (NSF-CRCD) project

The first two authors have been involved in a NSF sponsored Combined Research and Curriculum Development (CRCD) project. This project was funded in part due to the expertise of the investigators in the subject of particle technology, and in part due to the well-recognized need for education in this area. The CRCD program has been a very successful first attempt in correcting a "legacy of neglect" in particle technology at NJIT. Through the program a concentration of three courses was established: (1) *Introduction to Particle Technology: Fundamentals and Applications* (upper-level undergraduates and entry-level graduate students); (2) *Micro-level Modeling in Particle Technology* (graduate students); and (3) *Experiments and Simulations in Particle Technology* (undergraduates and graduate students). Each of the three courses was offered twice during the duration of the project. While the CRCD project has been a great success, it could not expose the subject of particle technology to the widest possible audience.

1.3 Objectives and goals

The primary objective of our current work is to incorporate subject matter in particle technology into the undergraduate curriculum so as to impact as wide an audience as possible. This is being done by bringing some of the results of the CRCD project into the mainstream curriculum with the active participation and advice from our industrial partners. The CRCD material was tested by offering undergraduate and graduate courses, which were taken as electives by a relatively small number of students. Current efforts will bring several of the experimental modules developed in the CRCD project into the Mechanical and Chemical Engineering core undergraduate laboratory by developing multimedia, web-based laboratory instructional material. This will help fulfill the following five objectives:

- incorporate important topics in particle technology into the core undergraduate curriculum without adding extra credits or requirements, and thus impacting a broader audience;
- benefit from having industrial collaboration for the practical implementation of the proposed modules;
- create a "learner-centered" environment for students, faculty and teaching assistants through an efficient, multimedia-based approach, by making available content-based information links on the web;
- make this material available for easy national dissemination; and
- create a "model" for multimedia manuals for other laboratory modules and courses.

2. Available experimental modules

The laboratory developed through the CRCD project resulted in the following experimental modules.

Table I: Completed Laboratory Modules in Particle Technology

Module	Description
Angle of repose	Students are asked to measure the angle of repose (AOR) for a variety of granular materials using four different classical methods (fixed height table, fixed base cone, tilting table and rotating cylinder). A digital camera is used to measure the AOR by the four methods and the results are compared. A new method based on magnetically assisted powder flow, developed in our laboratory, is also utilized [10].
Particle size analysis using sieves	The sieving apparatus used in our experiments is an Octagon 2000 Vibrated Siever with a set of sieves ranging from 25 microns (mesh # 500) to 4.0 mm (mesh # 5). Students analyze samples of coarse sand to obtain a size distribution curve as well as the cumulative distribution curve by weighing the residuals at each sieve. They also collect data to study the sieving rate.
Laser diffraction technique for particle size analysis	Students perform size analysis of samples obtained through a grinding experiment using a Malvern Mastersizer X laser diffraction particle size analyzer. The samples analyzed have a size range from a few microns to about 100 microns. Students learn about sample collection, preparation, and the use of the Mastersizer.
Size reduction/grinding with a ball mill	For the ball mill experiment, a ball mill (Paul Abbe) with a ceramic cylindrical jar and cylindrical Burundum Alumina as the grinding media is used. Students are asked to perform a simple grinding experiment to study the rate of change in the particle size distribution as a function of time. A challenge is to find a suitable test material capable of demonstrating the main features of the grinding process within a 2-3 hour lab period.

Material testing by Jenike shear cell for design of mass flow hoppers	The main issue in hopper design is the material testing procedure that provides the information about flowability and cohesiveness of the material needed to select the hopper slope and minimum outlet size. There are many different methods [11], although the Jenike method [12, 13] (which yields the Jenike yield locus) is considered the most reliable and the most widely used technique in industry. Students test materials such as flour, powdered sugar, and cornstarch. Highly cohesive materials (i.e., cornstarch) pose difficulties in obtaining reliable results. Moreover, the test apparatus is not user friendly, and the task is tedious and time consuming.
Rise of a large sphere in a vibrated bed	Students examine various behavioral regimes of a vibrated bed and make observations concerning the rise time of the large particle at different operating conditions.
Minimum sintering temperature of fluidized solids	The purpose of this experiment is to measure the minimum sintering temperature T_s (the temperature at which thermally induced surface softening and sintering begins), an intrinsic property of the solid particle surface.
Particle sedimentation	The falling ball viscometer apparatus consists of a glass cylinder (100 cm long x 10 cm diameter) containing a viscous fluid (UCON fluid 50-HB-3520). Sedimentation of small spheres is studied.
Powder mixing	Students perform mixing experiments using a rotating "V" blender. Powders of different colors are used, and mixing is characterized by the color index measured through a Minolta photo-spectrometer.
Hopper flows	Students use a transparent, two-dimensional, flexible hopper to understand mass flow and core flow within the hopper. They also study the effect of vertical vibrations on discharge from a vibrated hopper.
Rotating fluidized bed	Students learn the principles of a rotating fluidized bed and measure the minimum fluidization velocity at various operating speeds.
Dry particle coating	Students utilize the MAIC device for dry particle coating. Simple systems such as cornstarch coated with fumed silica or dry wax are used to study the change in flowability or hydrophilicity. The change in flowability is measured using the angle of repose devices. This experiment is directly related to our research, and is an environmentally friendly way to produce new, engineered particulates [14].

3. Industrial participation and selection of experiments for adaptation

Several Advisory Board (AB) members from the CRCD program gave lectures in class or participated in group discussions with our students. These participants included two industrial partners, Karl Jacob (Dow Chemical) who is also a co-author of this paper and Mark Bumiller (Malvern Instruments). In addition, they attended all of the AB meetings, and made themselves available for phone consultations. Both of them have once again showed their commitment to education in particle technology, and have pledged support to the current efforts. They have proposed several important experiments for both the Chemical and Mechanical Engineering laboratory courses. Karl Jacob stressed the importance of (1) fluidized beds, (2) hopper design for bulk material storage, and (3) milling and classification of bulk solid material. Mark Bumiller emphasized experiments involving (1) particle dispersion, (2) classifier efficiency, and (3) particle reduction (by milling) or particle growth (by crystallization). All of his suggestions involve the use of particle size analysis. Based on these suggestions, and subsequent telephonic discussions, an initial set of experiments has been selected for the proposed adaptation. From the initial set of four experiments described below, we will make the final selection of two or three for adaptation.

- *Material testing by direct shear cell and design of hoppers using the Jenike design procedure*. This is one of the most frequently used proceedure in powder and bulk handling practice. Both Chemical and Mechanical Engineering students need to have this knowledge, and they often make fundamental mistakes in design if not properly trained. Through this experiment, they would learn to understand the difference between fluid and bulk solid behavior. They will also understand the concepts of internal friction, wall friction, and material flow function.
- *Particle size reduction using a ball mill, and subsequent size analysis using sieves*. These experiments can teach students some very important lessons in size reduction, particle size classification and particle size distributions. Due to the incorporation of several different topics in one module, the use of multimedia and the Internet is essential so as to cover this material efficiently in a given amount of laboratory contact hours.
- *Fluidized beds*. Fluidized beds are used for many industrial operations, and even today, the study of fluidized bed is an important topic of research. For example, our group has found novel applications of rotating fluidized beds in dry particle coating [15] and self-cleaning wet scrubbing systems. We are building an instrumented conventional fluidized bed for studying specific variables as suggested by our industrial partners, such as the use of different powder materials (Geldart group A, B, C, and D particles), etc. The students will study and/or measure items such as, the concept of minimum fluidization and the difference between a packed and fluidized bed, pressure drop across the bed as a function of fluid velocity, observation of various regimes of fluidization, prediction of the fluid bed expanded height, etc. An interesting experimental design has been described in [16].
- *Particle size analysis using laser diffraction and particle dispersion*. This experiment serves two objectives. The student can learn about particle size analysis using a laser diffraction based instrument as well as investigate how to achieve proper particle dispersion. The available Malvern Mastersizer-X can be used for this

purpose. Students can also learn various diffraction theories and assumptions that they need to make about the optical properties of the material being studied.

4. Multimedia implementation

Discussions with the ME and ChE Laboratory Committees indicate that while existing experiments may require modification so as to keep the curriculum up to date, there is little room to add any new material. At present, a typical laboratory course contains 6 or 7 modules. In contrast, our CRCD based laboratory course contains 12 modules. We note however that the CRCD course was directed towards graduate or highly motivated undergraduate students; hence the students were expected to spend time outside the classroom for doing supplementary reading. There is another fundamental issue that also must be addressed. All existing laboratory modules are based on the material covered, at least in part, in some other core lecture courses. In the core lecture courses, there is little room left to incorporate particle technology, unless a comprehensive change in the curriculum is made. While this may be done in the long run, in the immediate future, it is clear that the material in particle technology is not present in the core lecture courses. Thus a good background in several topics in particle technology must be provided solely through the experimental modules. Another major problem is that most instructors currently involved in teaching laboratory courses are themselves not well versed in particle technology. Thus, effective teacher training is also necessary. These issues make this curriculum development a challenging task.

We plan to adopt a simple strategy in web-based multimedia module development. The main menu for each experiment will be placed as a sidebar, consisting of items such as, *Home*, *Introduction, Technical Background*, *Experimental Procedure*, *Sample Results*, *Procedure for Collecting and Analyzing Results*, *References* and *Links*. When each of the sidebar items is clicked, the student will be taken through a series of pages for that item. This is a simple web layout, but it is quite effective. There is an abundant use of multimedia in topics such as *Experimental Procedure*, *Sample Results*, and *Procedure for Collecting and Analyzing Results*. At all necessary places, useful web links will be provided. While the above material can be placed on a server for an easy access by anyone, it could be more conveniently placed on a CD-ROM to make licensing and copyright issues more manageable. Even when the material is placed on a CD-ROM, it utilizes html and/or Java type web based environment. Since all NJIT undergraduates have an NJIT provided PC for use at home, our software is based on a PC platform.

At the time of this writing, we have nearly finished the layout of the web-page for the Angle of Repose (AOR) experiment. Later, we plan to include this as a part of the material characterization experiments that also include the Jenike based direct-shear testing. The sample web layout is shown in Fig. 1.

Details of this and other experiments being developed will be presented at the conference and will be published in a future paper. In addition to the AOR experiments, html based multimedia manuals are being developed for the Jenike test experiment and for the conventional fluidized bed experiment. The conventional fluidized bed experiment was not included in the NSF-CRCD project. As suggested by our industrial partners, it is a highly desirable component in undergraduate education. Hence we have developed a simple and useful experiment based on the input from our industrial and academic advisors. The cylindrical section of this bed is removable, so that one of four pre-filled units can be easily placed for study. Each of the four units will be filled with a different type of powder (Geldart Group A, B, C, or D), so that a variety of fluidization phenomena can be studied.

5. Conclusions

Our ongoing project to develop particle technology experiments and associated multimedia-based laboratory manuals has been described. This project relies heavily on input from industrial and academic partners. We expect to add these experiments into the undergraduate core laboratory courses beginning in Fall 2001. Before finaladoption, several industrial and academic partners will be asked to evaluate the material and provide additional links and reference materials. After the modules have been thoroughly tested and revised through several offerings, they will be made available for wide dissemination to other universities.

Acknowledgement: We gratefully acknowledge financial support from the National Science Foundation (CTS-9910746) and the New Jersey Commission on Science and Technology. We also thank Robert Nodarse for building the fluidized bed, and Hiren Kumbhojkar for his contributions in developing the multimedia manual.

6. References

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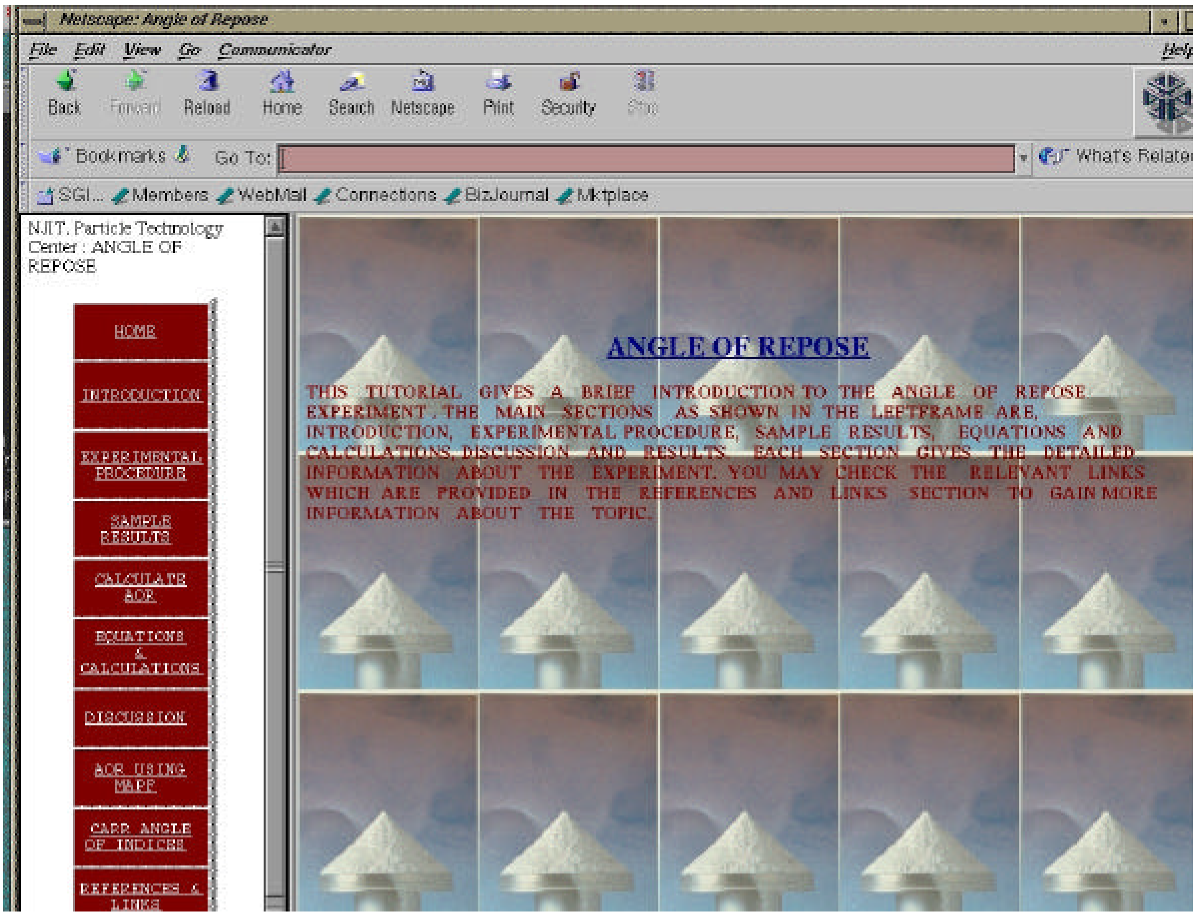

Fig. 1. Sample homepage layout for the Angle of Repose experiment