Session 3613

The Use of Sophisticated Process Design Software to Teach Basic ChE Principles Through the Design of a Ketchup Manufacturing Process in a Sophomore Laboratory Course

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Abstract:

Engineering process design software and simulators allow for the effective integration of design early in the engineering curriculum. Design experiences early in the curriculum offer opportunities to expose students to engineering applications that serve to increase understanding of technical material and enhance student interest in engineering. The use of sophisticated software has made it easier to introduce design concepts earlier in the curriculum. Students can use software for complex engineering calculations and designs in first year and sophomore courses. This can strengthen students' technical foundation and makes it easier for them to excel in subsequent engineering courses. This work describes the integration of design into a sophomore engineering laboratory course by using HYSYS@, a sophisticated process design software package. The goal of this work was to expose students to basic fluid mechanics and design principles through the design of a ketchup manufacturing facility using HYSYS@. Students were first exposed to design principles and developed conceptual design flow sheets for simple bench-scale experiments they performed in the laboratory. The topical focus of the course was fluid mechanics and students were exposed to the material via lectures and team problem synthesis and solution opportunities. Students also performed viscosity measurements on two brands of ketchup using a Brookfield viscometer and developed a preliminary flow sheet for a ketchup manufacturing process. The student response was positive. Exam results and class discussions indicated students assimilated the material well. As process design software becomes more available and easier to use, it will become a more integral part of engineering education providing opportunities to introduce students to engineering practice.

Introduction:

The Rowan University College of Engineering was established as a result of a $100 million gift from New Jersey Industrialists Henry and Betty Rowan in May, 1992. The

University, then Glassboro State College, formed an advisory council of leaders in education and engineering industries to develop the best plan for a college of engineering and an engineering curriculum to meet the needs of students, the profession and the country into the 21st Century. This effort led to the development of engineering curricula in the four major disciplines (chemical, civil, electrical and mechanical engineering) that integrated design throughout and incorporated liberal use of computers. Design is incorporated throughout the four years of the Rowan engineering curricula. There is a significant body of work that shows the importance of incorporating design in engineering courses[1-6]. Design serves to expose students to key components of engineering practice. In so doing, it enhances student understanding of complex material and serves to motivate and interest students. Incorporating design throughout the four years of the engineering curriculum is also consistent with the ABET 2000 accreditation criteria. One of the best ways to incorporate design into introductory engineering courses is to use engineering process software and simulators that expose students to complex design functions, without directly having to carry out the related complex calculations. This work focuses on the use of the HYSYS@ chemical engineering process software as part of an engineering laboratory course. The course aimed to introduce students to the design function and basic fluid mechanics principles through the development of a preliminary flow sheet for a ketchup manufacturing facility.

The Rowan Sophomore Engineering Clinic:

The Rowan Sophomore Engineering Clinic is a laboratory, project oriented course. It is modular in that different faculty present topics in the different engineering disciplines. The course is interdisciplinary and is required for all engineering students. The theme of the course is engineering design. The Clinic contains 1 s.h. of engineering content and 2 s.h. of written communication. The communication portion of the course is taught by faculty from the College of Communications. Every effort is made to integrate the communication and engineering portion of the Clinic. In this way, students have an integrated, multidisciplinary, writing intensive experience. Engineering modules are approximately four weeks long.

Fluids and their Properties Clinic Design Module:

The Fluids and their Properties Clinic Design Module was composed of three parts; design principles, basic fluid properties and flow, measurements and design of a ketchup manufacturing facility using HYSYS@. The module began with lecture and group exercises to expose students to design principles[1-6]. Students carried out two simple reactions in the laboratory and were asked to develop conceptual flow sheets for these products. Students carried out a simple polymerization reaction (polyvinyl alcohol and sodium borate) to make "slime". The product was to be marketed as a toy. The second reaction was a simple baking soda and vinegar reaction (with CO_2 release). This exposed students to the unique characteristics of multiphase processing. Again, students were asked to develop conceptual flow sheets for the process. As part of the development of conceptual flow sheets, students were asked to focus on aspects of the process that could require special consideration and equipment. The purpose of this section of the module was to enhance critical thinking skills while exposing students to the engineering method and design principles for simple and familiar processes. Connecting complex technical material with familiar concepts is an important tool to enhance student understanding[7]. Students were asked to consider the types of processes and products that would have specific characteristics and the implications that these would have in design. Much of this section of the module was team oriented and interactive. Students carried out the simple experiments in the laboratory and participated in lecture and group activities throughout.

The second part of the module consisted of lecture and group problem synthesis and solution activities dealing with fluid properties, rheology and processing. Students were exposed to basic fluid mechanics and rheology. This included basic calculations of Reynolds numbers, friction and turning losses in pipes, sizing of pumps, and mixer design. Concurrent with these activities, students began to learn to use the HYSYS@ software package to design a ketchup manufacturing facility. Ketchup manufacturing was chosen because of the high degree of familiarity that students have with the product[7]. Students also made viscosity measurements for two different brands of ketchup using Brookfield viscometers. It was necessary to devote some class time to teach the HYSYS@ software. Students were asked to develop their own recipes for ketchup and obtained recipes from the literature and web sites[8]. Students were also exposed to the regulations governing ketchup manufacturing. These were simple to find in web sites[9]. Students understood the importance of product composition and the constraints associated with regulations and specifications.

Development of Preliminary Flow Sheets for a Ketchup Manufacturing Process using HYSYS@

Once students had chosen the composition of the ketchup and had an understanding of its rheology and the regulations regarding ketchup manufacturing, they were ready to develop a preliminary flow sheet using HYSYS@, an interactive and sophisticated chemical engineering process design software. The goal was to develop a process flow sheet for a ketchup product with a specific viscosity. Students chose the viscosity based on their Brookfield viscosity measurements on two different brands of ketchup.

HYSYS@ operates via dialog boxes. The first choice students need to make before they can proceed with their design is the thermodynamic model for the process. This gives the opportunity to briefly discuss the importance of thermodynamics in processing, and to expose students to the different models available to describe mixture behavior. For simplicity, the UNIQUAC model was used in all designs. Figure 1 shows the first dialog box students work with on HYSYS@. Students then input the chemical components in their ketchup. This requires that student approximate properties for components (flavorings) that are not included in the HYSYS@ data bank. These are called hypothetical components. The dialog box for the input of components is shown in Figure 2. This gives an opportunity for discussions and group activities on the estimation of chemical properties. Students are exposed to the idea that all data and measurements may not be available.

Once the properties for the ketchup components were in the data bank, students specified streams, conditions and equipment. This gives an excellent opportunity to discuss the difference between chemical components of a process and the process streams. It also exposes students to processing equipment. For the vast majority of students, this was their first exposure to chemical processing equipment. Students can choose equipment from the icons shown in Figure 3. The figure also shows some of the equipment that students can choose to develop their flow sheet. In general, students chose stirred tanks (usually with heat input capability) as storage tanks for water/acetic acid/spices and tomato/water/acetic acid mixtures. These streams were heated and pumped into a mixer. From the mixer, the ketchup product was cooled a stored for bottling. HYSYS@ allows students to specify product properties. The software completes all mass and energy balances and calculates the stream properties necessary to obtain the specified product properties. Alternately, students can specify component properties and allow the software to calculate the resultant product properties. This exposed students to the delicate balances involved in design. Students developed preliminary flow sheets of varying degrees of complexity . Figures 4 a and b are sample flow sheets. Students were required to write a report complete with their flow sheet and work sheets for their process.

Conclusions:

The use of sophisticated engineering process software (HYSYS@) in a first semester sophomore clinic course proved to be very successful. Exams, homework, group activities and design reports clearly indicate that students learn the material and are enthusiastic about the project. However, the module was viewed positively by students and was highly successful because it included a support structure that allowed students to learn from basic principles. It was important to carry out the simple bench-scale experiments and to allow students time to develop the conceptual design flow sheets at the beginning of the module. This gave students a hands-on design principles experience with simple and familiar processes. It was also important to work with students as they learned to operate HYSYS@. Finally, the combination and flow of lecture, group activities and laboratory experiences played an important role in the success of the course. It is also critical to make certain that the use of software does not replace true understanding of the material by students. It is possible for students to use software and develop complex designs without the necessary understanding of basic principles that is critical to their development as engineers.

Engineering process design software and simulators can be powerful tools to enhance student learning and motivation. A design approach to lower level courses in the engineering curriculum can serve to excite and retain students. It also seems to positively impact student understanding and performance in later courses. Students presently taking a chemical engineering process principles course and fluid mechanics report that the clinic experience described here has served to enhance their understanding in these courses.

References

1. Fogler H.S. and S.E. LeBlanc, 1995, "Strategies for Creative Problem Solving," Prentice Hall PTR, Englewood Cliffs, NJ.
2. Ercolano, V., 1996, "Freshmen," ASEE Prism, April, 21-25.
3. McConica, C, 1996, "Freshman Design Course for Chemical Engineers," ASEE Chemical Engineering Education, 30(1), 76-80.
4. Wilczynski, V. and S.M. Douglas, 1995, "Integrating Design Across the Engineering Curriculum," A Report From the Trenches," ASEE Journal of Engineering Education, 84(3), 235-240.
5. Bucciarelli, L.L., 1994, "Designing Engineers," MIT Press, Cambridge, Mass.
6. Dym, C.L., 1994, "Engineering Design: Synthesis of Views," Cambridge University Press, NY, NY.
7. Perkins, D., 1993, "Teaching for Understanding." American Educator, 17(3), 8-13.
8. www.dynasys.com/~frederic/ketchup/ingredients.html
9. www.dynasys.com/~frederic/ketchup/section1.html

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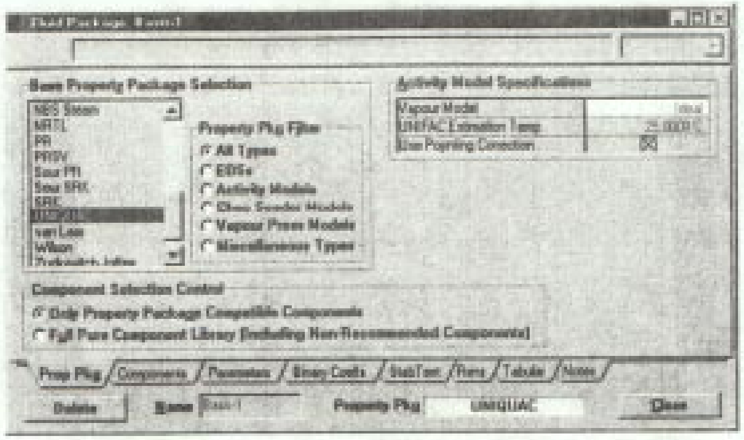


Figure 1: HYSYS® Fluids Package Dialog Box

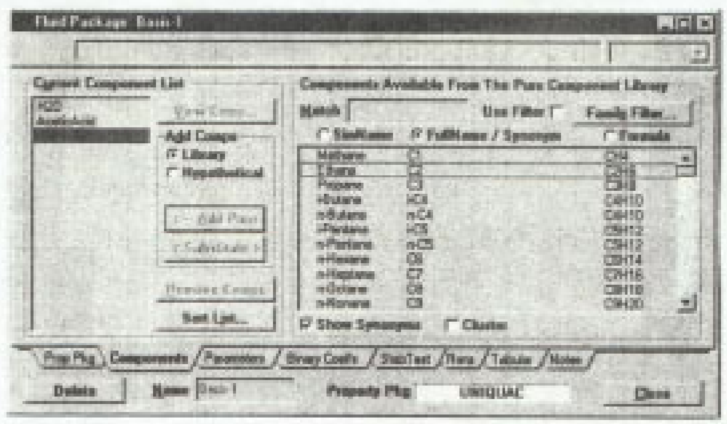


Figure 2: HYSYS® Component Input Dialog Box

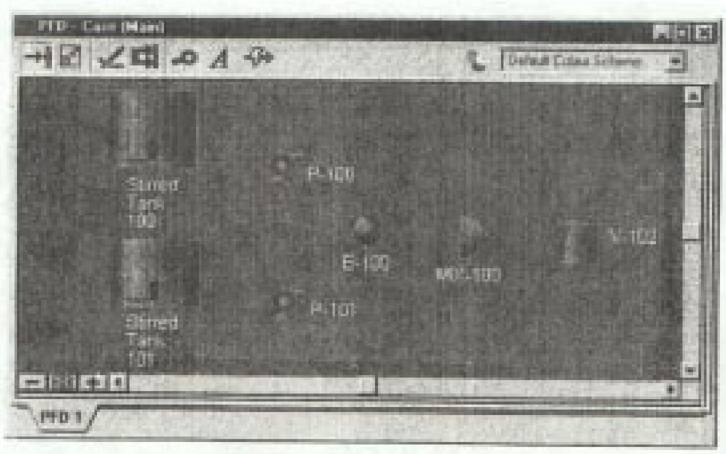
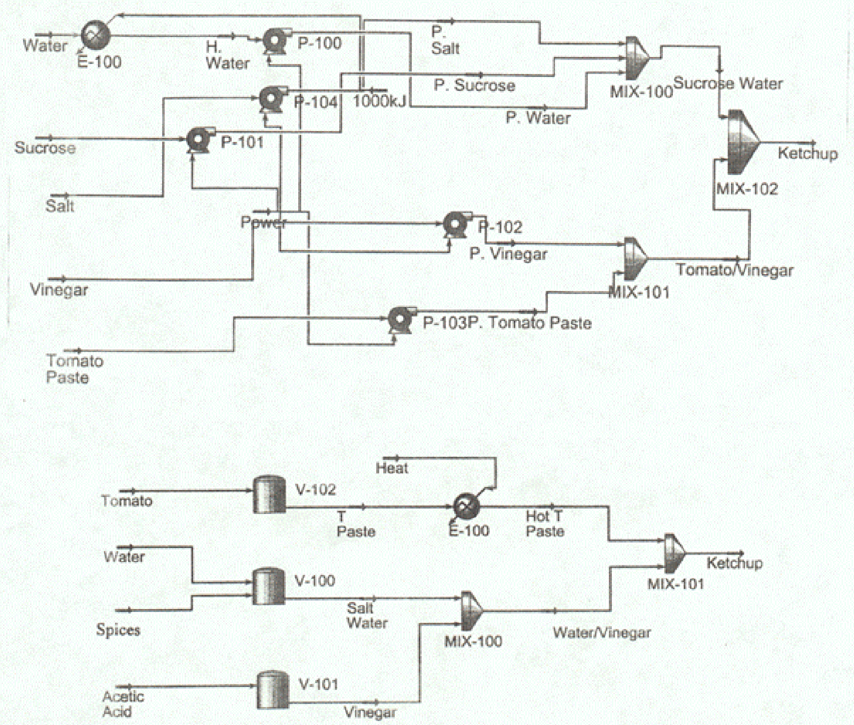


Figure 3: HYSYS® Flowsheet with Equipment Choices



Figures 4a and 4b: Sample Student Flowsheets