Product Design with the Aid of Finite Element Programs In Capstone Design Projects

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Abstract

The capstone chemical engineering design course projects are based on products as opposed to process. Furthermore, we are seeing increased reliance on computationally more advanced techniques such as finite element methods integrated reliably in commercially available software. In this presentation, we want to share our experience in use of COMSOL throughout several product design projects.

Introduction

The chemical engineering design effort that historically started with a focus on unit processes, equipment and plants soon transformed to concentrate around the processes and systematically evolved through computational tools such as flowsheet simulators as well as process synthesis methodologies. The concern for environment and safety became part of capstone courses in the past two decades. With evolving and expanding role of our profession in areas where value added differentiated products dominate and increased proximity of curricula to life sciences, the incorporation of product design in our curriculum was inevitable. This is in part brings forth need for incorporation of the supply chain and entire life cycle of the products in the design. The integration of process and product design would allow smooth flow of information from the design stage through the manufacturing stage. The integration of process and product design coupled with availability of software that can be effectively used for both necessitates utilization of computation tools such as finite element imbedded into mathematical software.

Capstone Design Course Series

Chemical Engineering programs usually have either one or two course design series. Probably like many institutions, at the University of South Florida, over the last three decades, we alternated between one course and two course series. At present, we have a first course where we focus on foundations of 'Product and Process Engineering' with a well defined design project. The second course 'Product and Process Design' is primarily centered on major design projects.

The first course was originally developed to teach strategies of process engineering in a systematic fashion where concepts were integrated through a project. Formal coverage of process economics, optimization, and uncertainty & risk analysis principles was coupled with a well defined simple design project with two to three degrees of freedom. The three credit course implied two hours per week of lecture time and three hours per week of tutorials and problem sessions.

The transformation to incorporate product design was gradual. Early to late nineties, we incorporated products primarily through market analysis. The economic analysis coverage was modified to incorporate key microeconomic concepts such as utility theory, supply demand analysis and pricing using game theory. In the past several years, the projects had a product design components and process design projects were modified accordingly. For example, a natural product extraction process can easily be modified to include multiple components and/or encapsulation stage. The other implications were choosing examples to reflect both the process and product realities. In that context, linear programming coverage touched on supply chain optimization. We also incorporated batch scheduling to deal with multi-product batch plants.

The second course, capstone design course, is centered on the projects that have varying degree of process or product emphasis but usually students end-up integrating both. There still two lecture and one three hour problem sessions per week. Some of lecturing is on general review of principles in the context of design and is with the aid of a sample pre-worked design project. Others are on new topics such as safety, green engineering, process synthesis and more rigorous sizing methods. The problem sessions enable applications particularly with the aid of computational tools such as flowsheet simulators. The first third of the course is lecture and tutorial intensive. At the beginning of the semester, students form groups and choose projects that are either from a list which is in part industry initiated or AIChE contest problem or self designed. Groups of three to four students work together and are mentored by teaching assistants, faculty. or industrial consultant/ There are weekly meetings and project requirements include a written report, oral presentation and poster presentation/ The projects have an individual as well as group component. The projects used over the last few years include:

- Self heating food, cappuccino, wash towel, stadium seats
- Self cooling beverage
- Food grade phosphoric acid
- Encapsulated Nutraceuticals
- Green Sail Boat

- Energy efficient amphibian for Tampa Bay Area
- Water purification system for Traveler
- Green Refrigerant
- LED plant
- Alcohol Free Beverage of your choice
- Targeted delivery drug of your choice
- Time release drug of your choice
- Wood-polymer composites
- Fuel cell based applications
- Dialysis Machine
- Chiral Separation Plant

The entire group is responsible from the design and following group report that includes the design and feasibility analysis. The group reports followed up with individual components of design and starts after the group report is submitted for evaluation. The individual report is based on detailed design of an element of the group report. The group has an oral presentation that is open to public. The last presentation is a poster presentation that is judged by the advisory board faculty and graduate students.

Finite Element Programs

The finite element programs benefit not only the product design element of the course but also process/equipment design. Historically, computation fluid dynamic packages were part of equipment design before product design. We found that distributed models provide a natural link between the engineering science courses such as transport phenomena and the design sequence.

Our students are introduced and solve a common tutorial problem in the workshop component of the course. They also use it in their product design as well as individual equipment design which may be considered product as well. Our students use COMSOL that interfaces well with MATLAB.

In the product design projects, we found them COMSOL to be particularly useful with timed release, targeted delivery, and self heating/cooling product design projects. This was in part due to the fact that models were simpler and readily available. Furthermore, these models were essential for prototyping the product. .