8.1: Optimization

Written by: Brittany Flaherty, Christine Curran, and Lauren Pakan

1.1 Definition

Optimization aims to obtain the best results in a given situation, or to minimize input to maximize benefit [1].

1.2 Engineering Application for Optimization

The following are examples of optimization across all engineering disciplines [1].

- Design of aircraft and aerospace structures for minimum weight
- Finding the optimal trajectories of space vehicles
- Design of civil engineering structures such as frames, foundations, bridges, towers, chimneys, and dams for minimum cost
- Minimum-weight design of structures for earthquake, wind, and other types of random loading
- Design of water resources systems for maximum benefit
- Optimal plastic design of structures
- Optimum design of linkages, cams, gears, machine tools, and other mechanical components
- Selection of machining conditions in metal-cutting processes for minimum production cost
- Design of material handling equipment such as conveyors, trucks, and cranes for minimum cost
- Design of pumps, turbines, and heat transfer equipment for maximum efficiency
• Optimum design of electrical machinery such as motors, generators, and transformers
• Optimum design of electrical networks
• Shortest route taken by a salesperson visiting various cities during one tour
• Optimal production planning, controlling, and scheduling
• Analysis of statistical data and building empirical models from experimental results to obtain the most accurate representation of the physical phenomenon
• Optimum design of chemical processing equipment and plants
• Design of optimum pipeline networks for process industries
• Selection of a site for an industry
• Planning of maintenance and replacement of equipment to reduce operating costs
• Inventory control
• Allocation of resources or services among several activities to maximize the benefit
• Controlling the waiting and idle times and queueing in production lines to reduce the costs
• Planning the best strategy to obtain maximum profit in the presence of a competitor
• Optimum design of control systems

1.3 Optimization across an Organization

The highest level of optimization includes the optimization of the raw material supply chain and the optimization of the packaging and product distribution chain. The plant wide optimization must consider documentation, maintenance, scheduling, and quality management considerations. Plant wide optimization resolves the conflict of objectives between the unit operations and the envelope strategies required to optimize the entire plant. Within the unit operations level multivariable optimization cannot be achieved when individual processing equipment is defective or when the control loops are not properly tuned. It is important that measurements be sampled fast enough, that controls loops be tuned for fast rates of recovery, and loop cycling be eliminated. When no mathematical model can describe a process, the process can only be optimized experimentally and empirical optimization is required [2].
1.4 Optimization Design

1.5 Constraints

Design constraints are physical limitations or restrictions that must be satisfied to produce an acceptable design [1].

- Operation conditions – safety, environmental
- Equipment constraints – e.g. pump rates
- Storage capacities
- Product quality and impurities

1.6 Optimization Situations

The following list describes common reasons for optimization in an industrial plant.

- Sales limited by production (e.g. reduce costs by minimizing downtime)
- Sales limited by market (e.g. be the "low cost producer")
- Plants with high throughput
- High raw material or energy consumption
- Product quality better than specifications
- Loss of valuable or hazardous components through waste stream
1.7 Real-Time Optimization

The following describes the steps in order to optimize a chemical engineering process.

1. Identify process variables
2. Select objective function (e.g. profit $$$)
3. Develop process model and constraints
4. Simplify model to objective function (e.g. linearization)
5. Compute the optimum
6. Perform sensitivity study

1.8 Industry Experience

Optimization can be applied to every aspect of a process. For example, at a refinery there are operators that work out in the units. Optimization can be applied to increase the operator/engineer communication by implementing "real-time" computer programs that allow the process engineers to see what is actually happening in the plant. This will help optimize process by allowing engineers to see what the conditions in the plant are in real time.

1.9 Pilot Plant Experience

Optimization of processes in a pilot plant will allow for more efficient scale-up to commercial size. In the ChE 460 course, four unit operations are optimized to produce soybean biodiesel. In order to optimize the reaction conversion, the project engineers vary catalyst concentration, agitation rate, and temperature. A design of experiment (DOE) is used to find the best set of input parameters.

1.10 References
