Topic:-Design optimization

Design Optimization

Design optimization is the process of finding the best design parameters that satisfy project requirements. Engineers typically use design of experiments (DOE), statistics, and optimization techniques to evaluate trade-offs and determine the best design. Design optimization often involves working in multiple design environments in order to evaluate the effects that design parameters have across interrelated physical domains.

Optimization is a component of design process .The design of systems can be formulated as problems of optimization where a measure of performance is to be optimized while satisfying all the constraints

Design variables

A set of parameters that describes the system (dimensions, material, load, …)

Design constraints

All systems are designed to perform within a given set of constraints.
The constraints must be influenced by the design variables (max. or min. values of design variables).

Objective function

A criterion is needed to judge whether or not a given design is better than another (cost, profit, weight, deflection, stress, ….).

Various Design Objectives

- Minimum Weight(under Allowable Stress).
- A PEM Fuel Cell Stack with Even Compression over Active Area (Minimum Stress Difference).
- Minimum Maximum Stress in the Structure Optimized Groove Dimension to Avoid Stress Concentration or Weakening of the Structure.

Why Design Optimization?

1. There are multiple solutions to the problem; and the optimal solution is to be identified.
2. There exist one or more objectives to accomplish and a measure of how well these objectives are accomplished (measurable performance).
3. Constraints of different forms (hard, soft) are imposed.
4. There are several key influencing variables. The change of their values will influence (either improve or worsen) the “measurable performance” and the degree of violation of the “constraints.

Aerodynamic Design of Missiles

The selection of flight profiles that yield the greatest performance plays a substantial role in the preliminary design of flight vehicles, since the use of ad-hoc profile or control p
olicies to evaluate competing configurations may inappropriately penalize the performance of one configuration over another. Thus, to guarantee the selection of the best vehicle design, it is important to optimize the profile and control policy for each configuration early in the design process.

Consider this example. For tactical missiles, the flight profiles are determined by the thrust and load factor (lift) histories. These histories can be controlled by a number of means including such techniques as using an angle of attack command history or an altitude/downrange schedule that the missile must follow. Each combination of missile design factors, desired missile performance, and system constraints results in a new set of optimal control parameters.

Optimization is the future, since the investment cost, efficiency, energy savings, etc. are critical are critical aspects. In particular, engineering disciplines need to develop mathematical and computational optimization methods to improve the efficiency of the processes.

Applications of Optimization

1. Design - determining design parameters that lead to the best "performance" of a mechanical structure, device, or system. "Core of engineering design, or the systematic approach to design" (Arora, 89)
2. Planning – production planning - minimizing manufacturing costs – management of financial resources - obtaining maximum profits – task planning (robot, traffic flow) - achieving best performances
3. Control and Manufacturing - identifying the optimal control parameters for the best performance (machining, trajectory, etc.)
4. Mathematical Modeling - curve and surface fitting of given data with minimum error

Optimization Problem

An optimization problem is a problem in which certain parameters (design variables) needed to be determined to achieve the best measurable performance (objective function) under given constraints.

What are common aspects in optimization problems?

- ✓ There are multiple solutions to the problem; and the optimal solution is to be identified.
- ✓ There exist one or more objectives to accomplish and a measure of how well these objectives are accomplished (measurable performance).
- ✓ Constraints of different forms (hard, soft) are imposed.
- ✓ There are several key influencing variables. The change of their values will influence (either improve or worsen) the "measurable performance" and the degree of violation of the "constraints."

Solution Methods

- Optimization can provide either
  - a closed-form solution, or
  - a numerical solution.
- Numerical optimization systematically and efficiently adjusts the influencing variables to find the solution that has the best performance, satisfying given constraints.
- Frequently, the design objective, or cost function cannot be expressed in the form of simple algebra .Computer programs have to be used to carryout the evaluation on the design objective or costs. For a given design variable, α, the value of the objective function, *f(α)*, can only be obtained using a numerical routine . In these cases, optimization can only be carried out numerically.

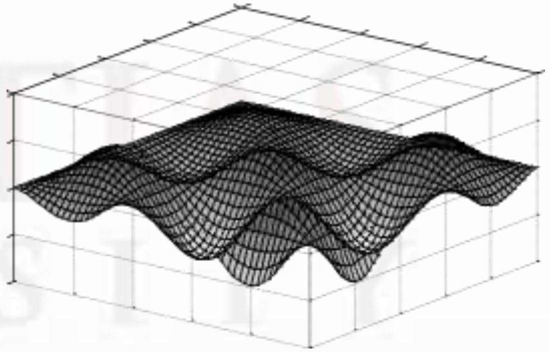
e.g. Minimize the maximum stress in a tents/tension structures using FEA.

- **Type of design variables**
  - optimization of continuous variables
  - integer programming (discrete variables)
  - mixed variables
- **Relations among design variables**
  - nonlinear programming
  - linear programming

$$e.g.\quad f(X) = Ae^{-x_1} + Bx_2^2$$

$$e.g.\quad f(X) = c_1x_1 + c_2x_2 + \ldots + c_nx_n$$

- **Type of optimization problems**
  - unconstrained optimization
  - constrained optimization
- **Capability of the search algorithm**
  - search for a local minimum
  - global optimization; multiple objectives; etc.



An Example Optimization Problem

Design of a thin wall tray with minimal material:

The tray has a specific volume, *V*, and a given height, *H*. The design problem is to select the length, *l*, and width, *w*, of the tray.

Given, $lwh = V$ $h = H$

A “workable design”:

$$lw = \frac{V}{H}$$

Pick either *l* or *w* and solve for others