Design & Analysis in Industry & Senior Design

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Design & Analysis in Industry

- Project initiated by product or process goal
  - Design process motivated by new product/process specification
    - Target new markets.
    - Reduce costs.
    - Improve product specifications for customer or marketing demands.
  - Generally, design is an enhancement to product or process as opposed to a brand new design.
Design Process in Industry

- Feasibility Study
- Assemble Technical Team
- Develop Project Schedule
- Project Implementation
  - Brainstorming, Designs, Analysis,
  - Selection, Approval,
  - Prototype, Test
- Assessment of Results
- Repeat as necessary
Feasibility Study is Made

- **Determine impact of proposed new process/product/features.**
  - New competitive edge, increase market share.
  - Open new markets.

- **Estimate rough costs and potential schedule.**
  - Is it physically possible? How long will it take?
  - What will it take ($ and time)?

- **Assess whether design is economically worthy?**
  - Implement or discard the idea.
  - Return on Investments (ROI), Timing
  - (Limited engineering, accounting, manufacturing resources.)
Assemble Technical Team

- Assign members from different appropriate disciplines:
  - Engineering
    - ME, CE, EE, IE, etc.
  - IT professionals
  - Technology specific vendors
  - Construction
  - Accounting, Marketing, etc.
  - Project Manager
Develop Project Schedule

- **Design and Analysis**: (Typical projects)
  - Product
  - Manufacturing process
  - Product data flow
- Prototyping/Prove-in
- Facility construction/equipment installation
- Testing and Analysis of Results
- Refinement of Design and Process
- Production Trials
- RTM (Ready to manufacture)
Design and Analysis
Requirements in Industry

- **Quantity matters**
  - How many are we going to make?
    - Is the design for a product?
    - How big is the market?
    - Is the design for an internal use production machine?
    - How costly is a mistake?

One, Ten, or ... Millions
Design and Analysis
Requirements
(How much analysis to do?)

- **Safety, Cost, and Quality matter**
  - **How costly is a mistake?**
    - Is personal safety affected by this design? (aircraft part, high speed equipment).
    - Is the cost of repair large? (Space shuttle, Hubbel telescope, production down-time)
    - Is the item a critical component of an expensive system (manufacturing line, luxury vehicle)?
Why Simulate & Analyze?

- Determine what *is* the problem to be solved. *Obvious symptom may not be the cause.*
- Cannot test everything (e.g., earthquakes, wind, etc).
- Analysis takes less time than build & test
- Virtual prototyping can also *cost less* than building & testing
- Evaluate *more* potential solutions.
- See what *new problems* solutions bring.
- Explore multiple solutions: *Determine best design*
  - Merit Analysis (Decision Matrix)
  - Controlled Convergence
Types of Analysis

- **Product/process function & performance**
  - Does it work like it should?
  - Is it faster or better than other solutions?

- **Product/process integrity**
  - Will it fail under some potential conditions?
  - Will battery last long enough?

- **Product/process human impact**
  - Ergonomics
  - Safety
  - Environmental effect (production & disposal)
Types of Design Analysis

- **Single-answer analysis:**
  - **Hand calcs:** A 600 lb. container is supported by the 3/8” rope. Determine if rope fails.
  - Do I have a large enough power supply? (V*A)

- **Performance analysis:**
  - Strength & Mechanical Analysis: **FEA (Pro/E, Ansys)**
  - P-Spice, MATLAB: Will new CPU work, be fast enough? Is robot stable?
  - Arena, Excel: Does the plant produce more?

- **Existing Data Bases:**
  - Ergonomics (Human Data)
Design and Analysis Efforts

- High Design and Analysis Efforts:
  - Inexpensive, high volume products (Telephones, razors)
  - Low volume, critical products (NASA, nuclear power)
  - Safety related products (elevators, eye lasers, hard hats, ladders)
  - Unable to test adequately (deep sea, costly production, etc.).
  - Senior design projects: )
Industry Design Example: Safety Related Components

- **Nuclear Power Plant Components**
  - Required by US Code of Federal Regulations
    - (e.g., 10CFR50)
  - Potential (hypothetical) failures are analyzed.
    - Loss of coolant accidents (LOCA)
    - Earthquakes
    - Operational transients
  - Extensive modeling and simulation. (FEA, CFD, FMA, PLC simulations)
Industry Design Examples: Large Volume Product

Every year the USA produces:

- 1 billion foil-lined fruit juice boxes
- 25 billion styrofoam cups
- 1.6 billion disposable pens
- 2 billion disposable razors
- 16 billion disposable diapers

High volume allows the cost of design and analysis to be spread over a large number of pieces.

- A mistake would be repeated millions or billions of times.
- Manufacturing tooling is expensive.
The Gillette Mach3 Turbo

- Gillette's triple-blade shaving system is “the most technologically advanced shaving system in the world provides a number of important design features.”
  
  - Protected by **45 patents**: "innovations, including new Anti-Friction™ blades, an ultra-soft protective skin guard, a patented Indicator® lubrication system and an improved razor handle."
  
  - $300 Million Development Cost
  
  - Generated $300 million in sales the first year
Gillette Fusion

- 5 Blade Shaving Surface™ Technology
- Protected by more than 70 patents, granted or pending
- P&G has about 27,000 patented technologies.
- 550 new patents last year.
The Design and Analysis approach changes with technology

- New design software tools.
- New easy integrated analysis software (e.g., P-spice, Pro/Engineer, Ansys, CFX, Simulink.....)
- Skill level requirements are lessening.
- Smaller cost to analyze.
- More cost to create and test than to virtual prototype.
- Direct Digital Manufacturing
Modeling and Analysis Time
Decreasing with Technology!

Model → Analysis

Stress Max Prim (Maximum)
Averaged Values
Original Model
LoadSet
Principal Units:
Inch lbm Second (Pro/E Default)
Simulate design before building

Fix errors
Optimize Parameters
DANGER!

- Inaccurate /over simplified models
  - Results may have convergence error
  - Model input may not be correct, or correctly applied
  - Boundary conditions, assumptions, etc.
  - Physical world differences from model

- Misapplied analysis and assumptions
  - Analysis limitations (linear, non-linear)
  - FEA makes a good engineer better… makes a bad engineer dangerous

- Testing still required!
Detailed Design & Manufacturing
Design Example in Optical Fiber Production

- Optical fiber produced in 2004 was over 55,000,000,000 meters.
  - (Enough to go around the world over 1300 times!)
  - Production machines generally produce on the order of 1 million meters of optical fiber per day.
  - Cost improvements on the order of 0.1% are significant in terms of dollars (millions of dollars per year).
  - Designs changes for tightening specifications, yield and productivity are done continuously.
Fiber Manufacturing Process
Many design opportunities.

Optical Fiber Manufacturing Process

Deposition
Sintering
Drawing
Inspection
Shipment
Problem: Customers Require More Uniform Lengths of Fiber on Spools, so short length sell for less.

- Customers purchase specific lengths of fiber (12.5km, 25km, 37.5km, 50km)
- The probability of breaks in the fiber during processing is somewhat random (lengths vary).
- Longer in-process lengths will reduce the manufactured breaks in the fiber.
- **Action from feasibility study:** Design and deploy machines and process with greater spooling capacity greater than 500 km per spool instead of 90 km.
Longer Lengths of Fiber on a Spool?

- Seems Simple: Get Larger Spools!.....but
- New machinery required for processing larger spools
- New materials handling equipment required
- New process procedures required
- New test equipment required
- In-process lag on quality feedback

Design and Manufacturing are a System. Change in one area effects the others. Planning and Project Management is required
Large Spool Project

- Feasibility Study
- Project schedule initially formed
- **Design and Analyses performed**
- Design selected & fully documented
- Prototypes constructed, evaluated, improved
- Prototypes installed and production line testing
- Data gathered and evaluated
- On-line design modifications while continue testing
- **Tests successful (from data), Recommendations**
- Design upgraded for production
- Implemented design in facility and retrofits
Testing & Analyses Performed and Repeated

- Feasibility of Process Change
- Process Design & Analyses
- Machine Design & Analyses
  - Mechanisms, structures
  - Control, electrical power
- Manufacturing/ Test Data: Did it do what we set out to accomplish. (machine & process)?

- REPEAT if needed
Generations of Development

First Prototype

Latest Design
Summary: Obtain Successful New Design Through Planned Design, Analysis & Testing:

- Good team
- Understanding of current systems and opportunities
- Thorough design and analysis
- Changing/Designing as a system.
  - Not just a collection of well-designed parts
- Effective exchange of information to all groups affected by a proposed change
- Extensive testing and evaluation
- Detailed planning and continuous project monitoring