Design and Analysis Applications in Industry and Senior Design

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My Experience

• Worked for two internationally known environmental consulting firms: CH2M Hill and Black & Veatch.
• I most often worked with a team of other engineers: Structural, geotechnical, electricals, mechanicals, instrumentation and process control engineers, and technicians.
**Design Process I**

- Our firms responded to Statement of Qualifications (SOQs) and Request for Proposals (RFPs).
- I wrote portions of proposals and made presentations to prospective clients if we were short-listed.
- If selected, we developed a Preliminary Design and presented it to client. Made revisions and held in-house reviews prior to preparing Final Design.

**Design Process II**

- Developed detailed *specifications* for all process equipment: pumps, blowers, clarifiers, aerators, mixers, etc. along with *detailed drawings* showing the layout of the facilities, plan and profile views of major processes.
- Developed *Operational Manuals* for major pieces of equipment.
- Once project was bid and construction began, reviewed shop drawings to see if met the design.
Product or Process Design

• Projects are initiated for new products, or new 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 an existing product or process, as opposed to a brand new design.

Design and Innovation is a Continuous Process in Industry

• Feasibility Study Conducted First
• Assemble Technical Team
• Develop Project Schedule
• Design & Implementation
  – Brainstorming, Designs, Analysis,
  – Selection, Approval,
  – Prototype, Test
• Assessment of Results
• Repeat as necessary
Feasibility Study is Made First

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

  ▪ Develop rough cost estimate and potential schedule.
  ▪ Is it physically possible? How long will it take?
  ▪ What will it take in terms of money and time?

  ▪ Assess whether design is economically worthy?
   ▪ Implement or discard the idea.
   ▪ Return on Investments (ROI) $$, (usually >30% is often required)
   ▪ Timing of implementation

Technical Team

• Assign members from appropriate disciplines:
  – Engineering
    • ME, CE, EE, IE, I & C, etc.
  – IT professionals (PC, networks)
  – Technology specific vendors
  – Construction
  – Accounting, Marketing, etc.
  – Project Manager
Develop Project Schedule

– **Design and Analysis**: (Typical projects)
  - Product design
  - Manufacturing process
  - Product data flow

– **Build Prototype and Prove Results**
– Refinement of Design and Process
– Testing and Analysis of Results
– Facility construction/equipment installation
– Production Trials
– Ready to Manufacture (RTM)

Feasibility & Specification

• **Feasibility Criteria**: Go versus No-Go features
  – **A MUST HAVE ATTRIBUTE**
    • Example: Must be electric power; must be less than 1 ton.

• **Specification**: Value target on performance measure
  – May need to translate **qualitative performance** to a specific value
    • Speed, Power, Current, Life
Brain Storm, Design Concepts, Analysis

- Brainstorm for creative ideas
- Come up with conceptual designs
  - Select 2 “best” design concepts to pursue
  - You will need to have a minimum of two designs for Sr Design; preferably three
- Use analysis performance of design to help you decide on what design to select.
- Continue more detailed analysis to show your design meets all feasibility and specifications.

Design and Analysis Requirements in Industry

- **Quantity matters**
  - How many are we going to make?

  - Is the design for a consumer product?
  - How big is the market?
  - Is the design for an internal use or a production machine?
Design and Analysis Requirements
(How much analysis to do?)

• Safety, Cost, and Quality Matter
  – How costly is a mistake?
    • Is personal safety affected by the 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 and Analyze?

• Determine what is root of the problem to be solved. 
  Obvious symptom or solution may not be right one.
• Cannot test everything (e.g., earthquakes, wind, etc).
• Analysis takes less time than build & test
• Virtual prototyping costs less than building
• Evaluate more potential solutions.
• See what new problems the solutions cause.
• Explore multiple solutions: Determine best design
  – Merit Analysis (Decision Matrix)
  – Controlled Convergence of a workable solution
Types of Analysis

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

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

- **Product/process: human impact?**
  - Ergonomics
  - Safety
  - Environmental effects (production & disposal of pollutants, waste streams)
  - Societal problems created (loss of jobs, relocation)

Types of Design Analysis

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

**Performance analysis:**
- Strength & Mechanical Analysis: Finite elements analysis (FEA) (**CREO**: 3-D CAD Software, **ANSYS**: simulation software)
- **P-**Spice (circuit simulator), **MATLAB**: Will new central processing unit work, be fast enough? Is robot stable?
- **Arena**: simulation software, **Excel**: Can the plant produce more?

**Ergonomics (Human Data):**
- Get the right: Size, force requirements, heights, etc.
Design and Analysis Efforts

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

Industry Analysis Example:
Safety Related Components

• Nuclear Power Plant Components
  – Required by U.S. Code of Federal Regulations
    • (e.g., 10CFR50)
  – Potential (hypothetical) failures are analyzed.
    – Loss of coolant accidents (LOCA)
    – Earthquakes
    – Operational transients (transitioning from 50 to 100% capacity).
  – Extensive modeling and simulation.
    (FEA, Computational Fluid Dynamics
    – Failure Mode Analysis,
    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 Mach3Turbo

- 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 in 2010 for P&G.

The Design and Analysis Approach
Changes with Technology

• New design software tools.
• New easy integrated analysis software
  – (e.g., P-spice, Creo, SolidWorks, 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: 3-D printing.
Modeling and Analysis Time Decreasing with Technology!

Simulate Design Before Building

Fix errors
Optimize Parameters
DANGER!

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

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

• Testing still required!

Design is often Iterative
(many approaches)
Case Study in Design for 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 Schematic

http://www.fiberinstrumentsales.com/blog/how-fiber-optics-are-made
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 fabrication 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 100 km.

Longer Lengths of Fiber on a Spool?

- Solution 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 and fully documented
- Prototypes constructed, evaluated, improved
- Prototypes installed for production line testing
- Data gathered and evaluated
- On-line design modifications while continue testing
- Tests Complete (data),
- Recommendations made
- Revise Design for production
- Implemented design in facility and retrofits

Testing and 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

Take up machine for optical fiber.

Latest Design

Summary:
Obtain Successful New Designs through Planned Design, Analysis & Testing:

- **Understand current situation:** 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 still needed**