Design for Manufacturing

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4. The Design Process

- Understand the overall design process

Overview of the design process

- Sources of design projects
  - With market demand
  - Without market demand
- With market demand
  - About 80% are market driven
  - It is necessary to find out what the customer wants

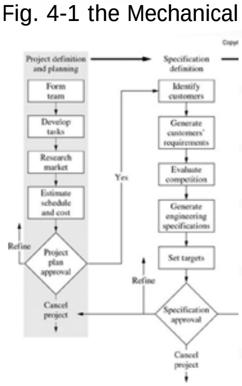
Overview of the design process

- Without market demand
  - No way to recover costs
  - Utilizing new technology
  - Extensive investment for develop new technologies
  - To be matched by market demand
  - Post-it notes
  - Walkman

Overview of the design process

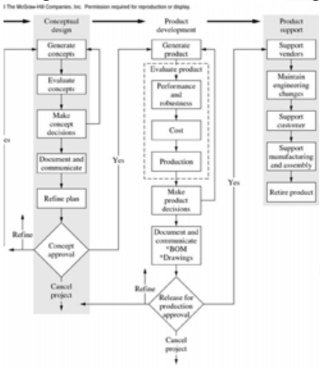
- Redesign
  - Include new technology in an existing product
  - To fix a problem with an exiting product
  - Reduce cost or simplify manufacturing

Fig. 4-1 the Mechanical Design Process



Courtesy: David Ullman – Mechanical Design Process, McGraw Hill, 2003

Fig. 4-1 the Mechanical Design Process



Courtesy: David Ullman – Mechanical Design Process, McGraw Hill, 2003

Example – Space Shuttle

- Rocket booster
- Reusable
- Disassembled and refueled
- Assembled in the field

Fig. 4-2 Space shuttle ready for launch

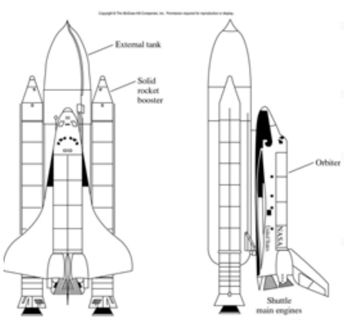


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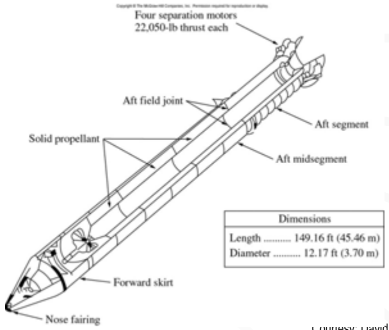
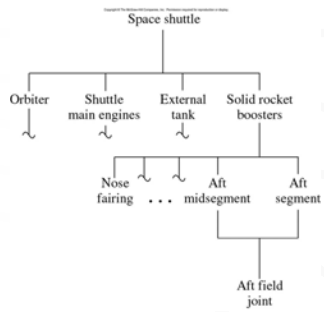
Fig. 4-3 Major parts of the solid rocket booster



Courtesy: David Ullman – Mechanical Design Process, McGraw Hill, 2003

Fig. 4-4 Space Shuttle partial design decomposition

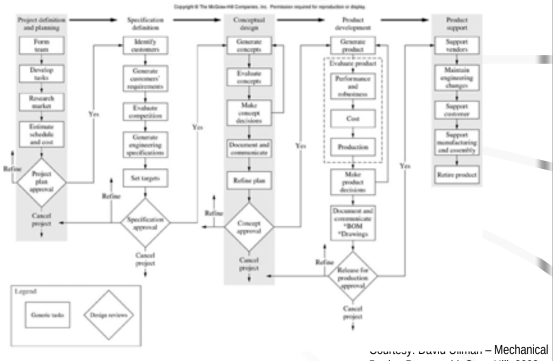


Courtesy: David Ullman – Mechanical Design Process, McGraw Hill, 2003

Project Planning

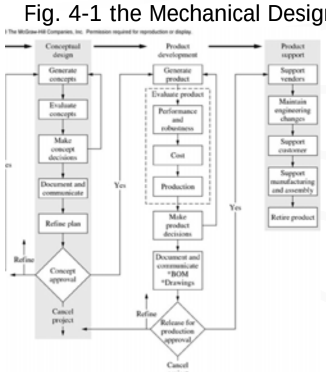
- Speculating about the unknowns
- Planning will be easier if there is a similar project done earlier
- Completely new project is very difficult
- Design teams
- 15 people worked on the design of the field joint of the rocket booster for a one-year period

Fig. 4-1 the Mechanical Design Process



Courtesy: David Ullman – Mechanical Design Process, McGraw Hill, 2003

Fig. 4-1 the Mechanical Design Process



Courtesy: David Ullman – Mechanical Design Process, McGraw Hill, 2003

Specifications Definition

- Goal is to understand the problem and lay the foundation for the remainder of the design project
- Since the design problem is poorly defined, finding out exactly what the design problem is can be a major undertaking.

Specifications Definition

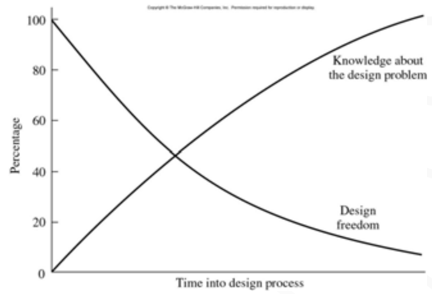
- First step – Identify customers
  - – Generate customer requirements
- Evaluate the customer requirements
  - – Generate engineering specifications
- Set targets for performance
- All phases are iterative in nature
- Conduct a design review meeting (Feb. 5th)

- Design is an iterative process.
- The necessary number of iterations always seems like one more than you have done.
- This is true at any point during the project.

Conceptual Design

- Generate concepts based on results of planning and specification definition phases.
- Developing a concept into a product without prior effort on the earlier phases of the design process is like building a house with no foundation.
- Evaluate concepts against requirements
- Best alternative with the least expenditure of time and other resources needed to gain knowledge.

Fig. 1-11 The design process paradox



Courtesy: David Ullman – Mechanical Design Process, McGraw Hill, 2003

Product Development

- Ideally refine the best concept into a product
- Many a design projects starts here
- Starting a project with a single conceptual design in mind, without concern for the earlier phases, is poor design practice.

Product Development

- Products generated are evaluated for performance, cost and production
- It is an iterative process

Product Support

- Design engineer's responsibility will not end with the release of product documentation
- He may be involved in
  - Manufacturing and assembly support
  - Support for vendors
  - Help introducing the product to the customer
  - Engineering change process
  - Product retirement

The Design Process: Designing Quality into Products

- Inspecting quality into the product
- Quality cannot be manufactured or inspected into a product, it must be designed into it.
- Engineering best practices

The Design Process: Designing Quality into Products

- Genius is 1 percent inspiration and 99 percent perspiration
  - Thomas Edison

Table 4.1 Best practices presented in this text

Project planning (Chap. 5)
Forming design teams
Generating a product development plan

Specification development (Chap. 6)
Understanding the design problem
Developing customers' requirements
Assessing the competition
Generating engineering requirements
Establishing engineering targets

Conceptual design
Generating concepts (Chap. 7)
- Functional decomposition
- Generating concepts from functions

Evaluating concepts (Chap. 8)
- Judging feasibility
- Assessing technology readiness
- Go/no-go screening
- Using the decision matrix

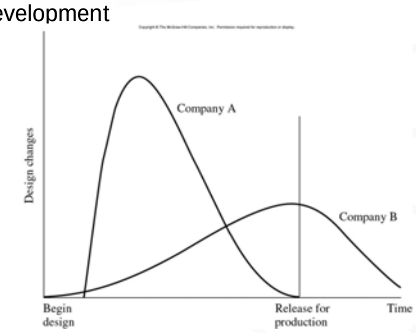
Product development
Generating the product (Chap. 10)
- Form generation from function
- Material and process selection

Evaluating the product (Chaps. 11 and 12)
- Evaluating functional changes
- Evaluating performance
- Sensitivity analysis
- Tolerance analysis
- Robust design
- Design for cost
- Value engineering
- Design for manufacture
- Design for assembly
- Design for reliability
- Design for the environment

Applying for a patent

Product support (Chap. 13)
Support vendors
Maintain engineering change
Support customers
Support manufacturing and assembly

Fig. 4-5 Engineering changes during automobile development



Courtesy: David Ullman – Mechanical Design Process, McGraw Hill, 2003

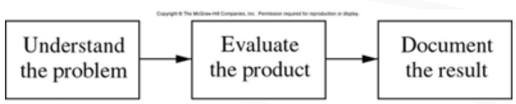
Simple design process examples

- What size SAE grade 5 bolt should be used to fasten together two pieces of 1045 sheet steel, each 4 mm thick and 60 mm wide, which are lapped over each other and loaded with 100 N?
- Design a joint to fasten together two pieces of 1045 sheet steel, each 4 mm thick and 60 mm wide, which are lapped over each other and loaded with 100 N?

Fig. 4-6 Design of a simple lap joint

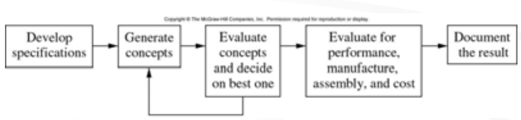
Courtesy: David Ullman – Mechanical Design Process, McGraw Hill, 2003

Fig. 4-7 Design process for a simple lap joint



Courtesy: David Ullman – Mechanical Design Process, McGraw Hill, 2003

Fig. 4-8 Design process for a more complex lap joint



Courtesy: David Ullman – Mechanical Design Process, McGraw Hill, 2003

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Design failure in space shuttle challenger

- Jan 28, 1986 – Challenger exploded
  - Killed the crew
  - Space exploration stopped for 2 years
- The Space Shuttle's Solid Rocket Booster problem began with the faulty design of its joint and increased as both NASA and contractor management first failed to recognize it as a problem,then failed to fix it and finally treated it as an acceptable flight risk.

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Design failure in space shuttle challenger

- The booster that failed is one of two solid – fuel boosters designed to help the shuttle to reach the orbital velocity.
- Booster is assembled in site
- Aft field joint is one of the joints made during the final field assembly

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Fig. 4-2 Space shuttle ready for launch

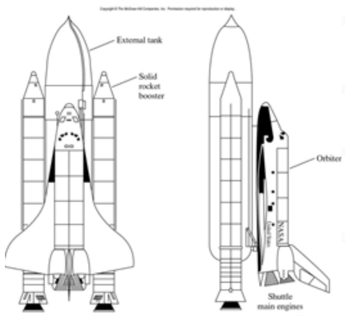

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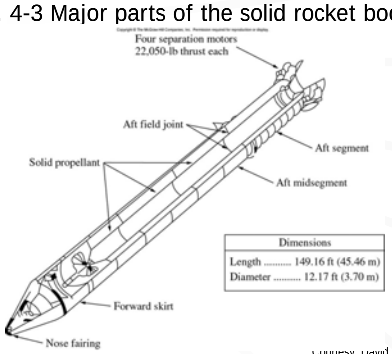
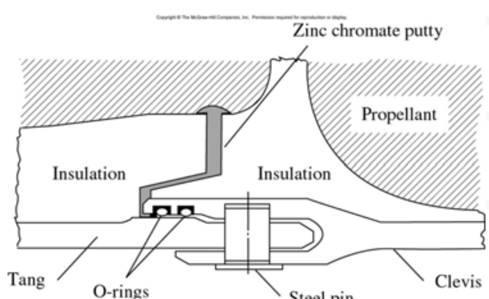
Fig. 4-3 Major parts of the solid rocket booster



Courtesy: David Ullman – Mechanical Design Process, McGraw Hill, 2003

Fig. 4-9 Cross section of the booster field joint



Courtesy: David Ullman – Mechanical Design Process, McGraw Hill, 2003

Design failure in space shuttle challenger

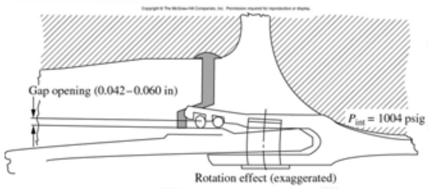
- Based on similar design for Titan III rocket
  - Larger in diameter than Titan
  - Reusable unlike Titan which is used only once
  - The Challenger booster's O-rings took the pressure of combustion, whereas the single O-ring in the Titan did not. In the Titan the insulation was tight fitting and the O-ring had only to take the pressure of any leakage through the insulation

Design failure in space shuttle challenger

- Based on similar design for Titan III rocket
  - The tang in the Challenger booster joint was longer and flexed under pressure more than that on the Titan.
  - O-ring on Challenger was made from sections glued together, whereas that on the Titan was molded as one piece.

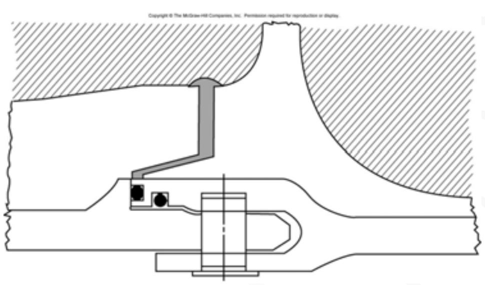
Design failure in space shuttle challenger

Fig. 4-10 Pressurized field joint



Courtesy: David Ullman – Mechanical Design Process, McGraw Hill, 2003

Fig. 4-11 Alternative design for O-ring seals



Courtesy: David Ullman – Mechanical Design Process, McGraw Hill, 2003

Communication during the Design Process

- Design Records
  - Design notebook
- Documents communicating with Management
  - Design review meetings
- Documents communicating the Final Design
  - Detail drawings, and written documentation

Introduction of a Sample Design Problem

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Fig. 4-12 The BikeE CT (1998 model)

Courtesy: David Ullman – Mechanical Design Process, McGraw Hill, 2003

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Summary

- Design is a process not just building hardware. (Tim Carver, Oregon State University student, 2000).
- Developing your only concept into a product without effort on the earlier phases of the design process is like building a house with no foundation.
- Quality can not be manufactured or inspected into a product. It must be designed in.

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Summary

- Design is an iterative process. The necessary number of iterations is one more than the number you currently have done. This is true at any point in time. (John R. Page, Rules of Engineering)
- Follow the KISS rule: Keep It Simple Stupid!

Questions and Comments