Design of Machine Elements (DOME)
MENG 375

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Lecture 01
Introduction to Engineering Design

Lecture Outline

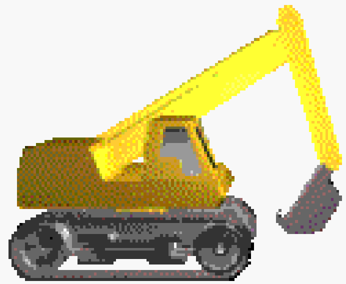
- Design
- Mechanical Engineering Design
- Phases and Interactions of the Design Process
- Design Tools and Resources
- The Design Engineer's Professional Responsibilities
- Standards and Codes
- Economics
- Safety and Product Liability
- Stress and Strength
- Uncertainty
- Design Factor and Factor of Safety
- Reliability
- Dimensions and Tolerances

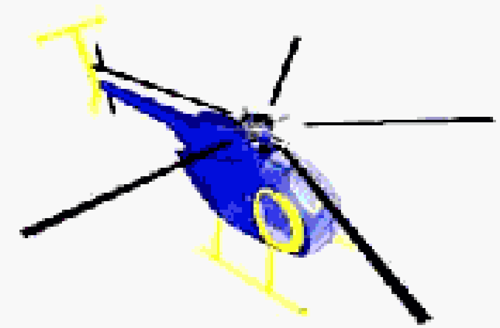
Source: Animation factory

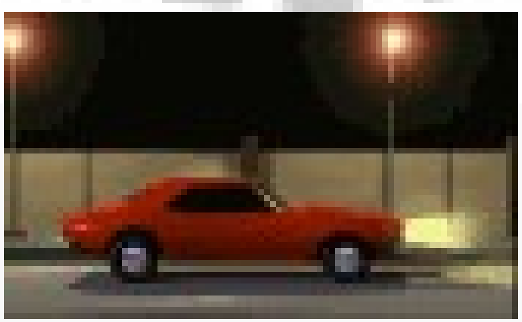
Course Assessment

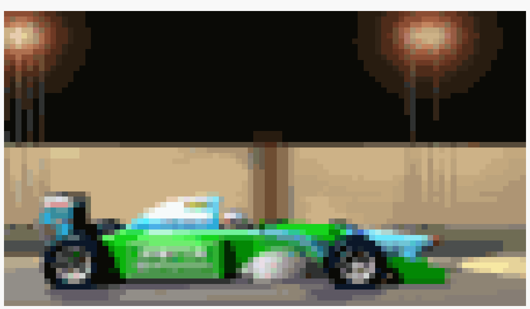
- Quizzes (10%)
- Assignments (5%)
- Project (20%)
- Tests (25%; test 1-12/03/2020, test 2- 20/04/2020)
- Final (40%)

Combination of various Elements =>Complex Machines

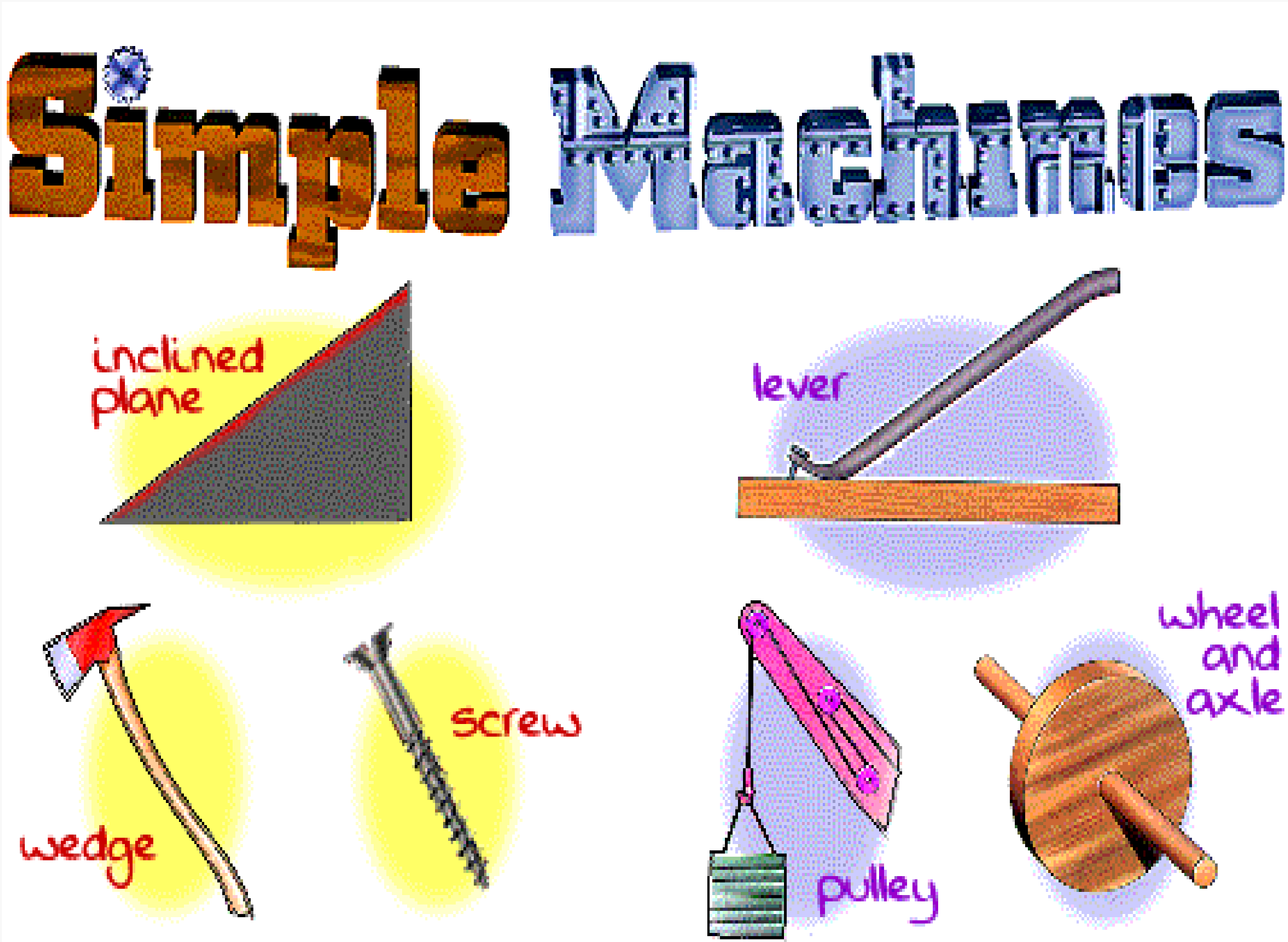


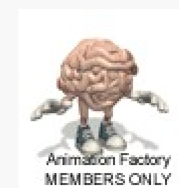




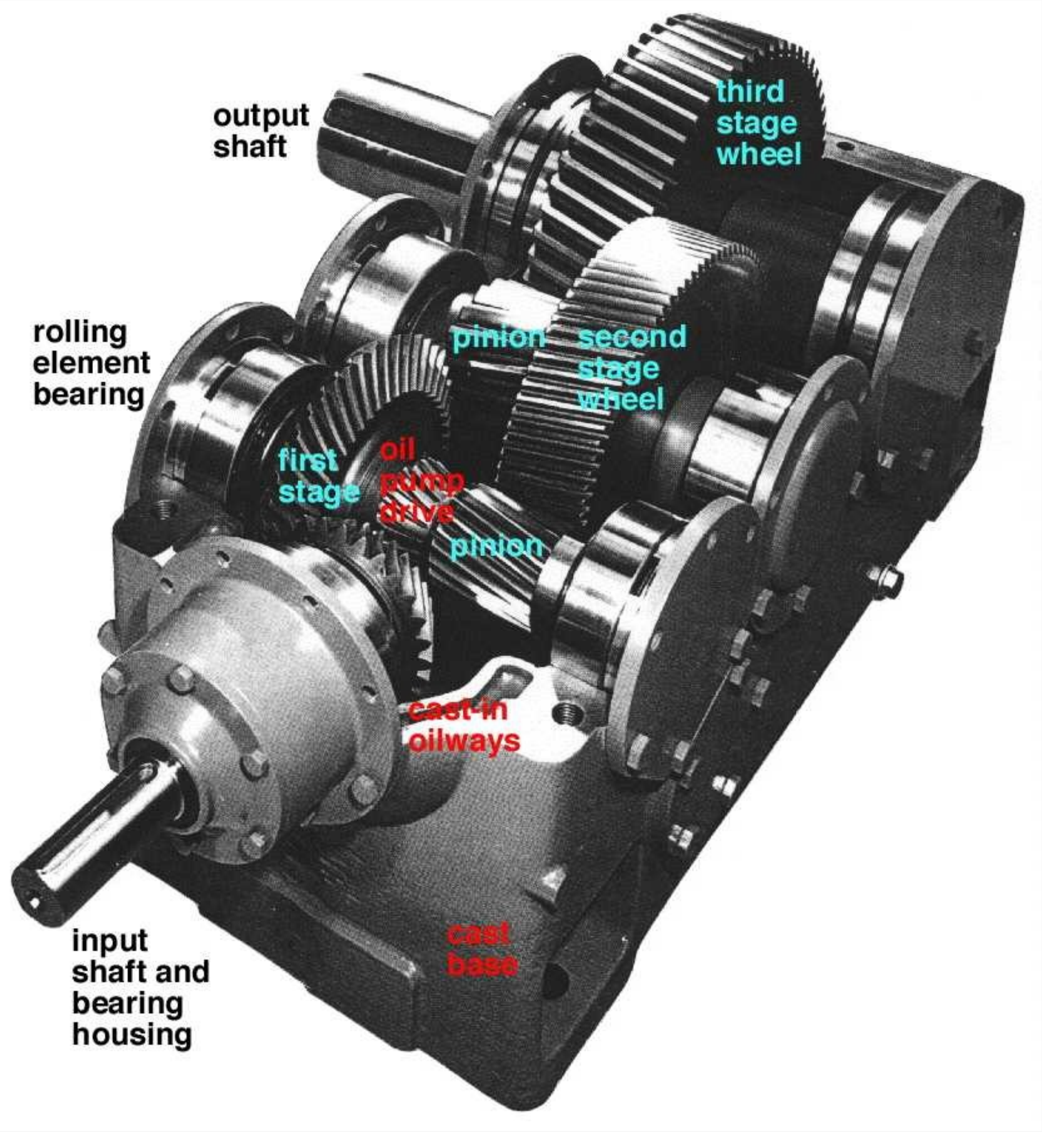


What is a Machine?





Gear Box



output shaft
third stage wheel
rolling element bearing
pinion
second stage wheel
first stage
oil pump drive
pinion
cast-in oilways
cast base
input shaft and bearing housing

Books and Resources

Text Book

▪Mechanical Engineering Design 10th Edition By Joseph .E. Shigley, Charles Mischke and Richard G. Budynas Publisher McGraw Hill

Reference Books

▪Design of Machine Elements by M.F. Spotts and T.E.Shoup

Publisher Pearson Education

▪ Fundamentals of Machine Component Design by Jvinall & Marshek

▪ Engineering Design by Dieter

▪A text Book of Machine Design by RS Khurmi, JK Ghupta, S Chand

Office Hours : Monday to Wednesday 04 pm-05pm Please book a free slot by sending an email and mention the topic to be discussed.

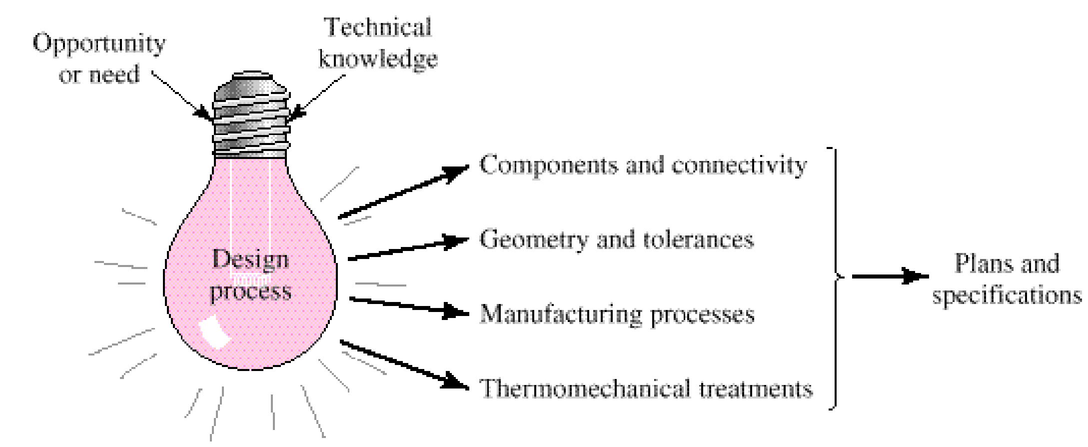
Recommended Computer Softwares

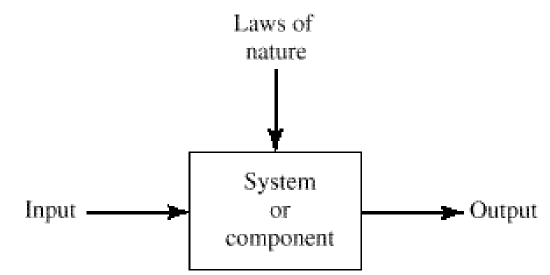
- AutoCAD
- Pro-Engineer
- Ansys

Use of computer in the Course will be highly encouraged.

Design

- Design is either to formulate a plan for the satisfaction of a specified need or to solve a problem





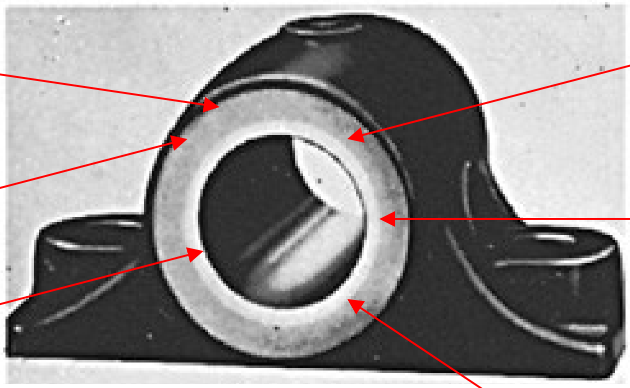
Name of the game	To find	Given	Skill involved
Analysis	Output	System, input, laws	Deduction
Inverse analysis	Input	System, output, laws	Deduction
Science	Laws	System, input, output	Induction
Engineering	System	Input, output, laws	Synthesis

Design

- Process requires innovation, iteration, and decision-making
- Communication-intensive
- Products should be
  - Functional
  - Safe
  - Reliable
  - Competitive
  - Usable
  - Manufacturable
  - Marketable

Mechanical Engineering Design

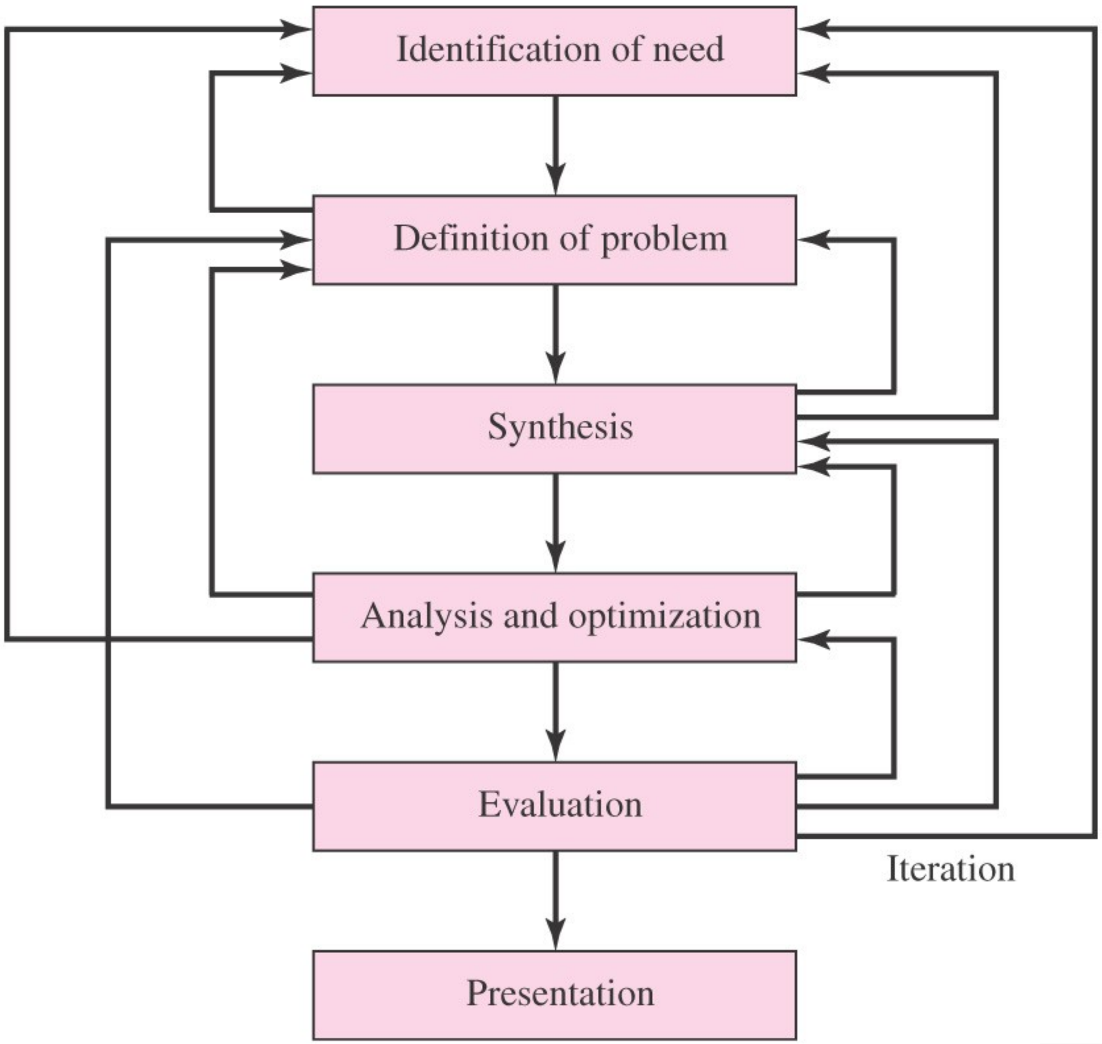
- Mechanical engineering design involves all the disciplines of mechanical engineering.
- Example
  - Journal bearing: fluid flow, heat transfer, friction, energy transport, material selection, thermomechanical treatments, statistical descriptions, etc.



Journal Bearing

The Design Process

- Iterative in nature
- Requires initial estimation, followed by continued refinement



Design Considerations

- Some characteristics that influence the design

1	Functionality	14	Noise
2	Strength/stress	15	Styling
3	Distortion/deflection/stiffness	16	Shape
4	Wear	17	Size
5	Corrosion	18	Control
6	Safety	19	Thermal properties
7	Reliability	20	Surface
8	Manufacturability	21	Lubrication
9	Utility	22	Marketability
10	Cost	23	Maintenance
11	Friction	24	Volume
12	Weight	25	Liability
13	Life	26	Remanufacturing/resource recovery

Computational Tools

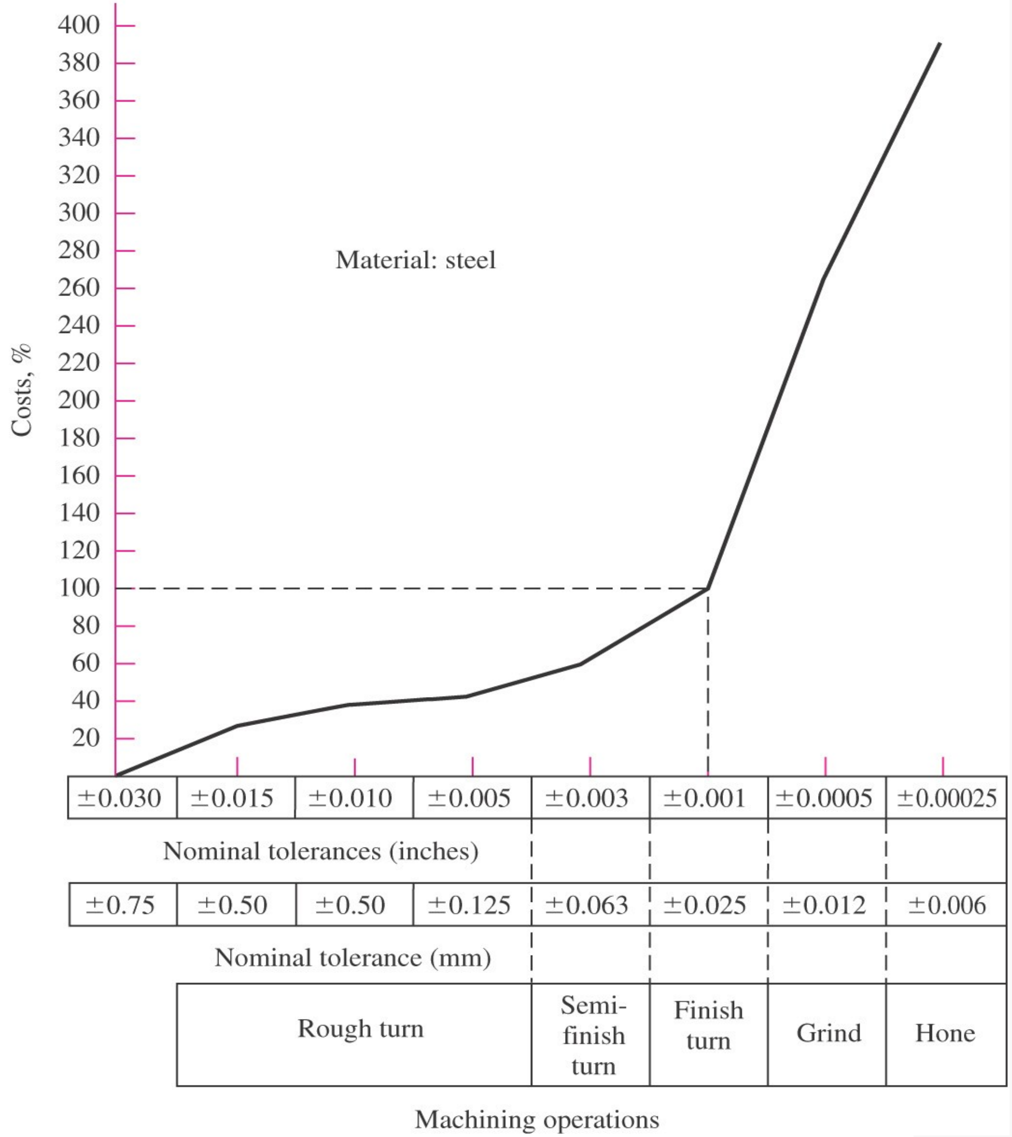
- Computer-Aided Engineering (CAE)
  - Any use of the computer and software to aid in the engineering process
- Computer-Aided Design (CAD)
  - Drafting, 3-D solid modeling, etc.
- Computer-Aided Manufacturing (CAM)
  - CNC toolpath, rapid prototyping, etc.
- Engineering analysis and simulation
  - Finite element, fluid flow, dynamic analysis, motion, etc.
- Math solvers
  - Spreadsheet, procedural programming language, equation solver, etc.

Acquiring Technical Information

- Libraries
  - ➢ Engineering handbooks, textbooks, journals, patents, etc.
- Government sources
  - ➢ Government agencies, U.S. Patent and Trademark, National Institute for Standards and Technology, etc.
- Professional Societies (conferences, publications, etc.)
  - ➢ American Society of Mechanical Engineers, Society of Manufacturing Engineers, Society of Automotive Engineers, etc.
- Commercial vendors
  - ➢ Catalogs, technical literature, test data, etc.
- Internet
  - ➢ Access to much of the above information

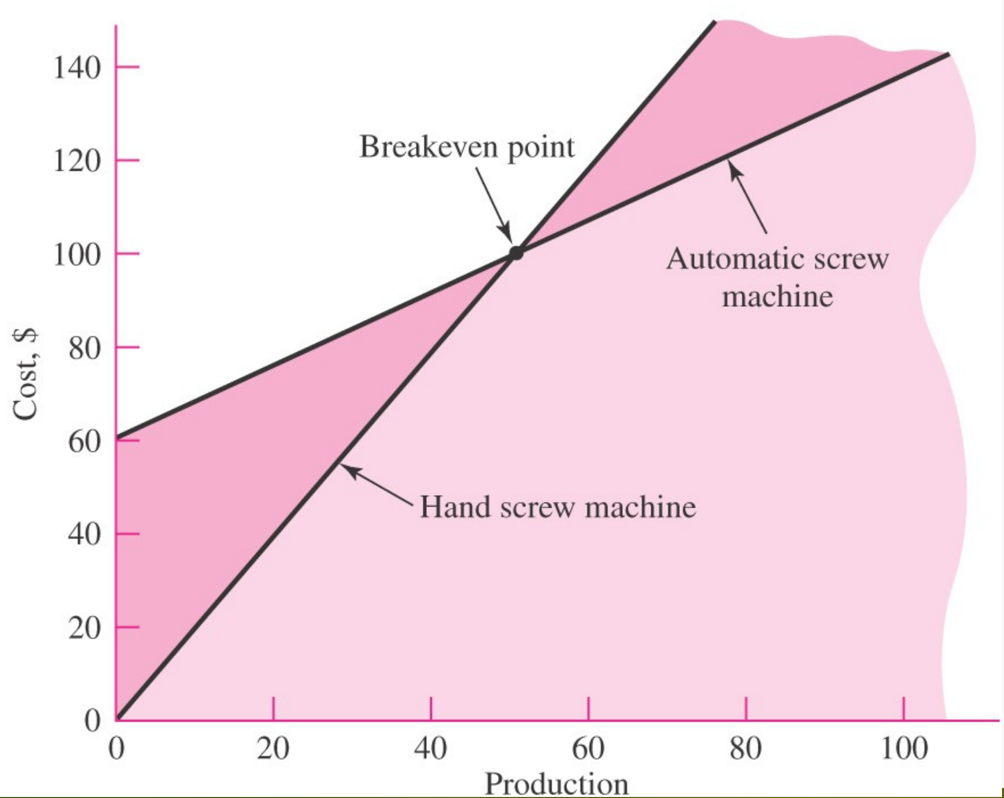
Tolerances

- Close tolerances generally increase cost
  - Require additional processing steps
  - Require additional inspection
  - Require machines with lower production rates



Breakeven Points

- A cost comparison between two possible production methods
- Often there is a breakeven point on quantity of production
- Automatic screw machine
  - 25 parts/hr
  - 3 hr setup
  - $20/hr labor cost
- Hand screw machine
  - 10 parts/hr
  - Minimal setup
  - $20/hr labor cost
- Breakeven at 50 units



Safety and Product Liability

- *Strict Liability* concept generally prevails in U.S.
- Manufacturer is liable for damage or harm that results because of a defect.
- Negligence need not be proved.
- Calls for good engineering in analysis and design, quality control, and comprehensive testing.

Stress and Strength

- **Strength**
  - An inherent property of a material or of a mechanical element
  - Depends on treatment and processing
  - May or may not be uniform throughout the part
  - Examples: Ultimate strength, yield strength
- **Stress**
  - A state property at a specific point within a body
  - Primarily a function of load and geometry
  - Sometimes also a function of temperature and processing

Uncertainty

- Common sources of uncertainty in stress or strength

- Composition of material and the effect of variation on properties.
- Variations in properties from place to place within a bar of stock.
- Effect of processing locally, or nearby, on properties.
- Effect of nearby assemblies such as weldments and shrink fits on stress conditions.
- Effect of thermomechanical treatment on properties.
- Intensity and distribution of loading.
- Validity of mathematical models used to represent reality.
- Intensity of stress concentrations.
- Influence of time on strength and geometry.
- Effect of corrosion.
- Effect of wear.
- Uncertainty as to the length of any list of uncertainties.

Uncertainty

- **Stochastic method**
  - Based on statistical nature of the design parameters
  - Focus on the probability of survival of the design's function (reliability)
  - Often limited by availability of statistical data

Uncertainty

- **Deterministic method**
  - Establishes a *design factor*, n_d
  - Based on absolute uncertainties of a *loss-of-function parameter* and a *maximum allowable parameter*

$$n_d = \frac{\text{loss-of-function parameter}}{\text{maximum allowable parameter}} \qquad (1\text{–}1)$$

  - **If, for example, the parameter is load, then**

$$\text{Maximum allowable load} = \frac{\text{loss-of-function load}}{n_d} \qquad (1\text{–}2)$$

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Design Factor Method

- Often used when statistical data is not available
- Since stress may not vary linearly with load, it is more common to express the design factor in terms of strength and stress.

$$n_d = \frac{\text{loss-of-function strength}}{\text{allowable stress}} = \frac{S}{\sigma (\text{or } \tau)} \qquad (1\text{–}3)$$

- All loss-of-function modes must be analyzed, and the mode with the smallest design factor governs.
- Stress and strength terms must be of the same type and units.
- Stress and strength must apply to the same critical location in the part.
- The *factor of safety* is the realized design factor of the final design, including rounding up to standard size or available components.

End

Reliability

- *Reliability*, R – The statistical measure of the probability that a mechanical element will not fail in use
- *Probability of Failure*, p_f – the number of instances of failures per total number of possible instances

$$R = 1 - p_f \qquad (1\text{–}4)$$

- Example: If 1000 parts are manufactured, with 6 of the parts failing, the reliability is

$$R = 1 - \frac{6}{1000} = 0.994$$ **or 99.4 %**

End

Reliability

- *Series System* – a system that is deemed to have failed if any component within the system fails
- The overall reliability of a series system is the product of the reliabilities of the individual components.

$$R = \prod_{i=1}^{n} R_i \qquad (1\text{-}5)$$

- Example: A shaft with two bearings having reliabilities of 95% and 98% has an overall reliability of

$$\boldsymbol{R = R_1 R_2 = 0.95\,(0.98) = 0.93 \qquad \text{or } 93\%}$$

Dimensions and Tolerances

- ***Nominal size*** – The size we use in speaking of an element.
  - Is not required to match the actual dimension
- ***Limits*** – The stated maximum and minimum dimensions
- ***Tolerance*** – The difference between the two limits
- ***Bilateral tolerance*** – The variation in both directions from the basic dimension, e.g. 1.005 ± 0.002 in.
- ***Unilateral tolerance*** – The basic dimension is taken as one of the limits, and variation is permitted in only one direction, e.g.

$$1.005 \begin{smallmatrix} +0.004 \\ -0.000 \end{smallmatrix} \text{ in}$$

End

Dimensions and Tolerances

- ***Clearance*** – Refers to the difference in sizes of two mating cylindrical parts such as a bolt and a hole.
  - Assumes the internal member is smaller than the external member
  - *Diametral clearance* – difference in the two diameters
  - *Radial clearance* – difference in the two radii
- ***Interference*** – The opposite of clearance, when the internal member is larger than the external member
- ***Allowance*** – The minimum stated clearance or the maximum stated interference or mating parts

The Design Engineer's Professional Responsibilities

- Satisfy the needs of the customer in a competent, responsible, ethical, and professional manner.
- Some key advise for a professional engineer
  - Be competent
  - Keep current in field of practice
  - Keep good documentation
  - Ensure good and timely communication
  - Act professionally and ethically

Standards and Codes

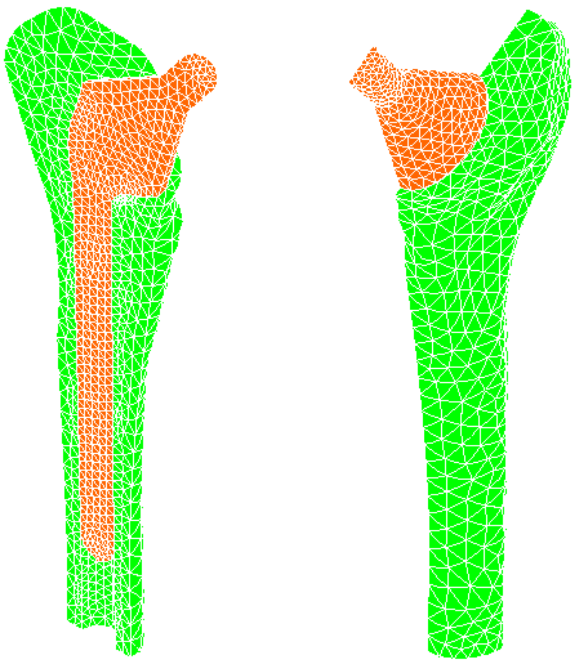
- Standard
  - A set of specifications for parts, materials, or processes
  - Intended to achieve uniformity, efficiency, and a specified quality
  - Limits the multitude of variations
- Code
  - A set of specifications for the analysis, design, manufacture, and construction of something
  - To achieve a specified degree of safety, efficiency, and performance or quality
  - Does not imply absolute safety
- Various organizations establish and publish standards and codes for common and/or critical industries

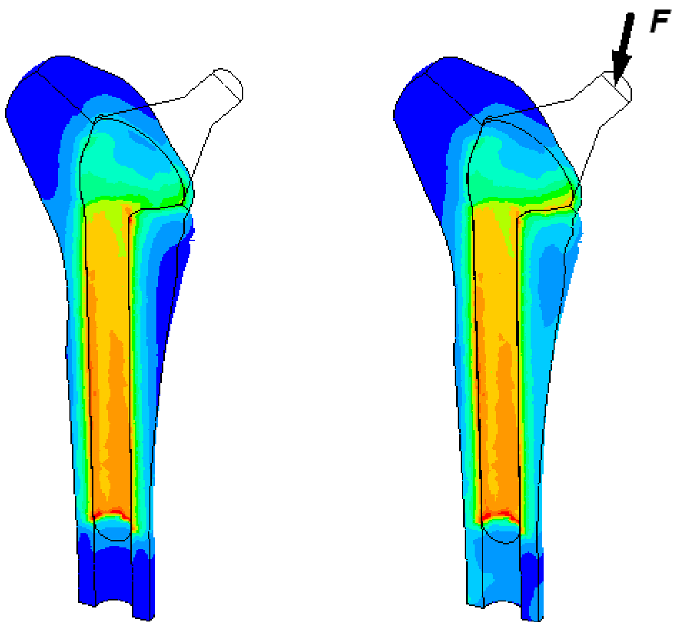
Standards and Codes

- Some organizations that establish standards and codes of particular interest to mechanical engineers:

Aluminum Association (AA)
American Bearing Manufacturers Association (ABMA)
American Gear Manufacturers Association (AGMA)
American Institute of Steel Construction (AISC)
American Iron and Steel Institute (AISI)
American National Standards Institute (ANSI)
American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)
American Society of Mechanical Engineers (ASME)
American Society of Testing and Materials (ASTM)
American Welding Society (AWS)
ASM International
British Standards Institution (BSI)
Industrial Fasteners Institute (IFI)
Institute of Transportation Engineers (ITE)
Institution of Mechanical Engineers (IMechE)
International Bureau of Weights and Measures (BIPM)
International Federation of Robotics (IFR)
International Standards Organization (ISO)
National Association of Power Engineers (NAPE)
National Institute for Standards and Technology (NIST)
Society of Automotive Engineers (SAE)

Sample Application: Hip Implant

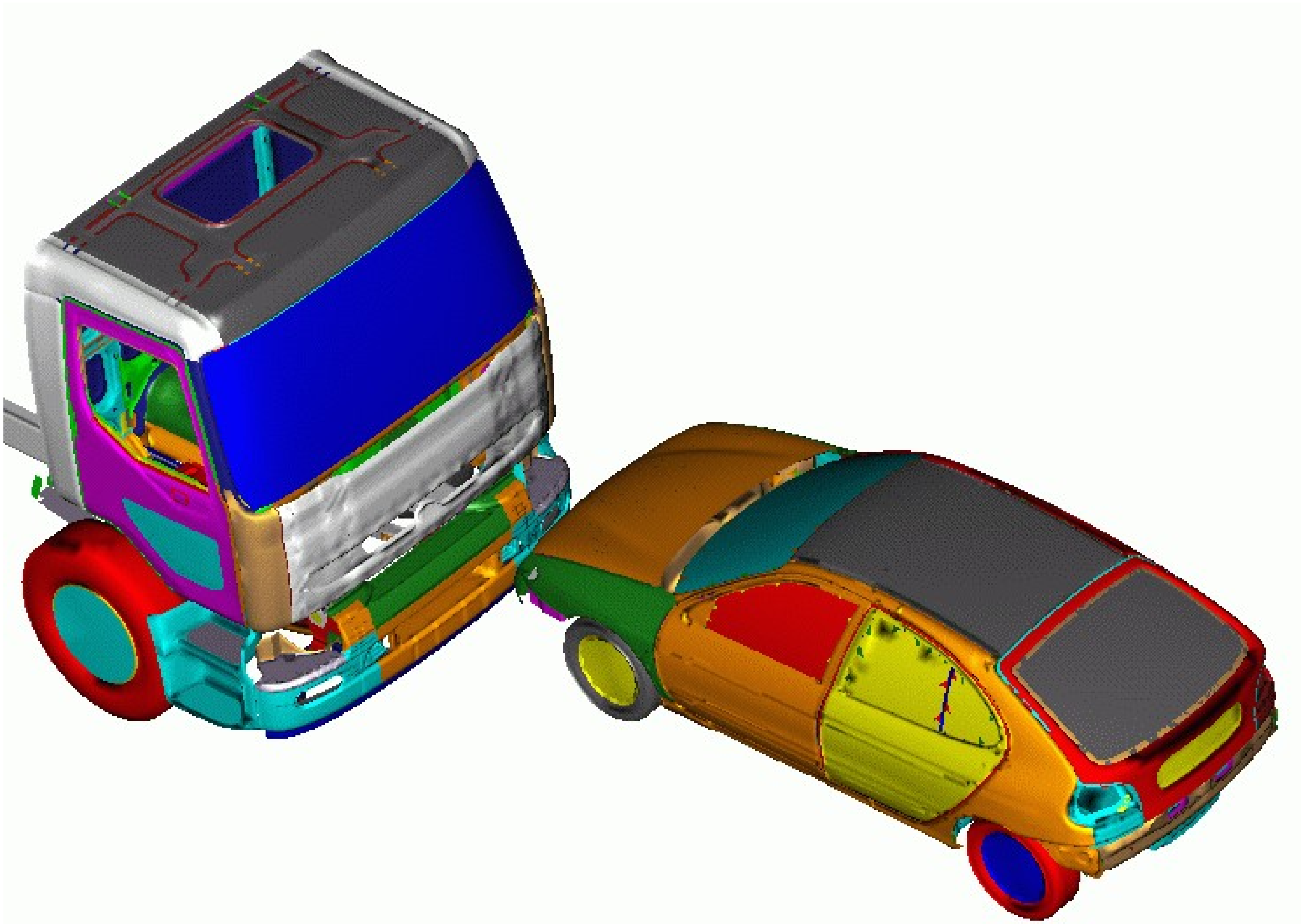




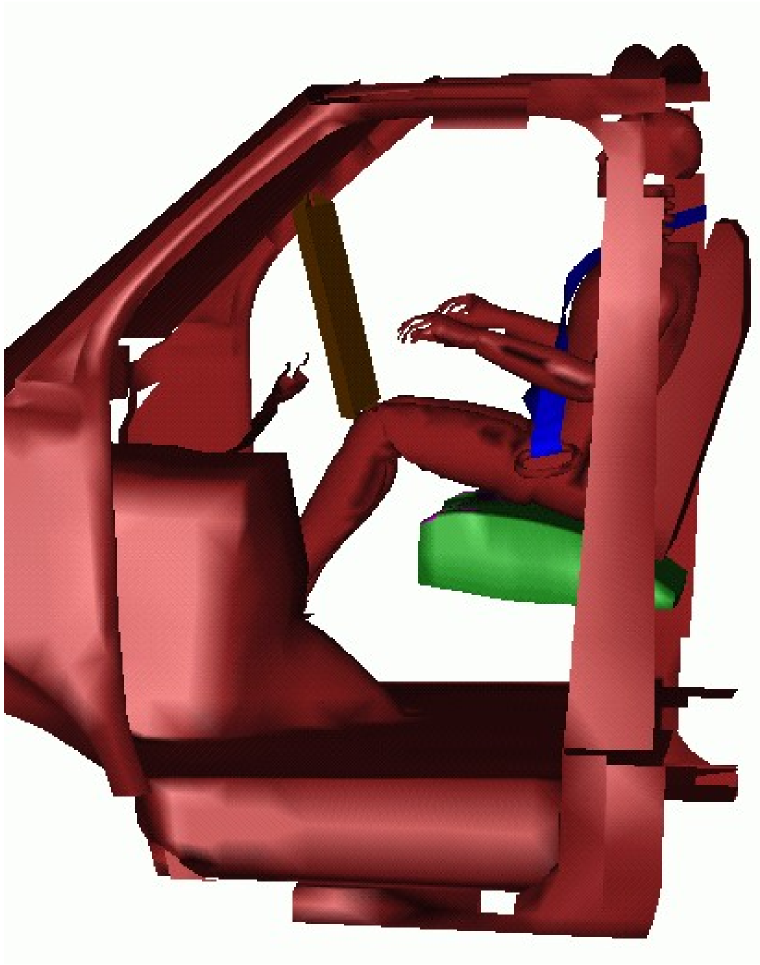
a) Due to interference fit with implant.

b) Due to interference fit and applied load.

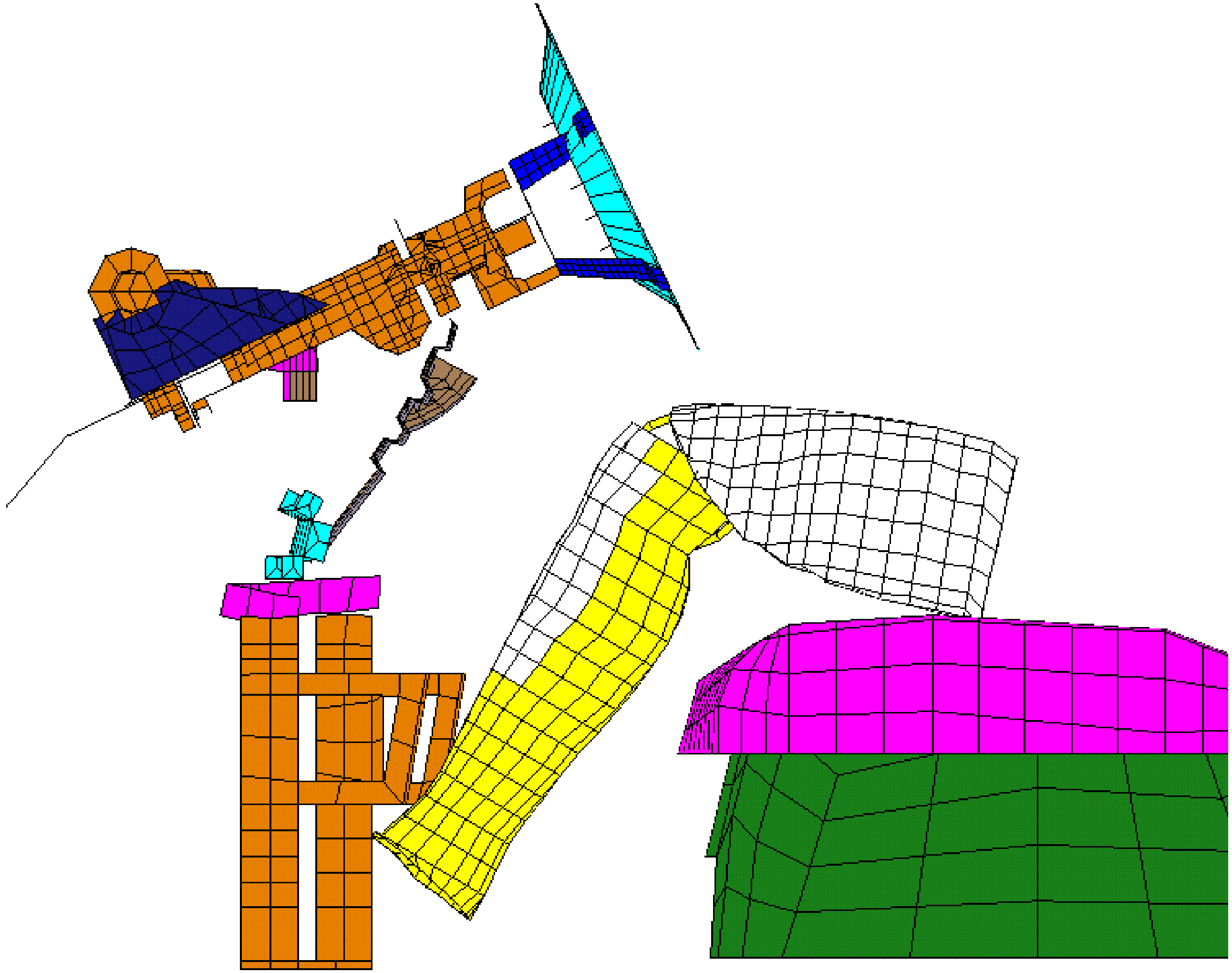
Application: Crash Simulation



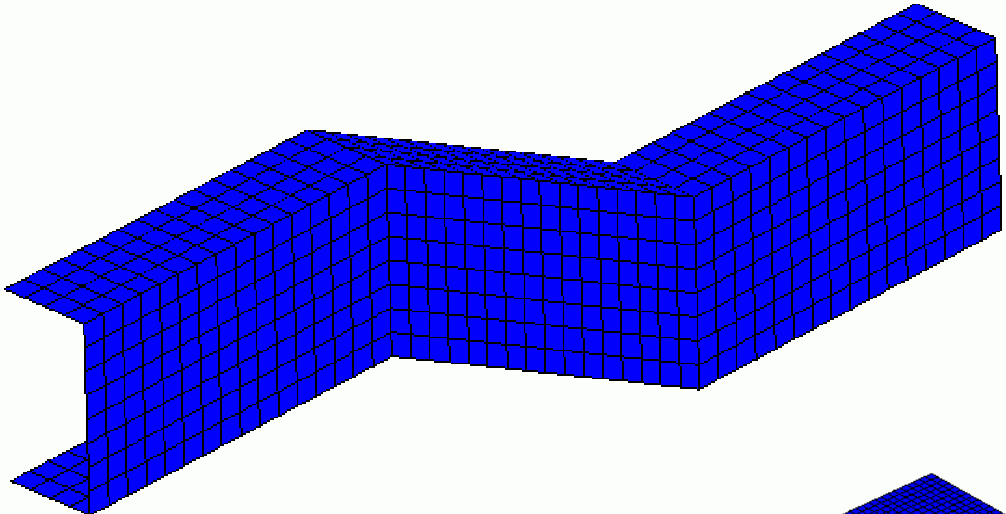
Frontal Crash: Belted and Unbelted Driver

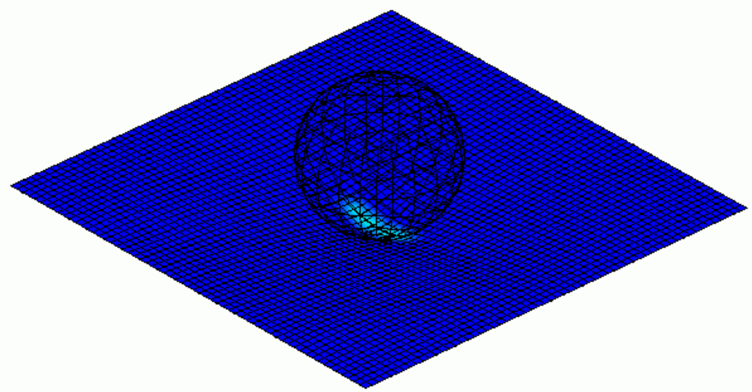


Knee Protection

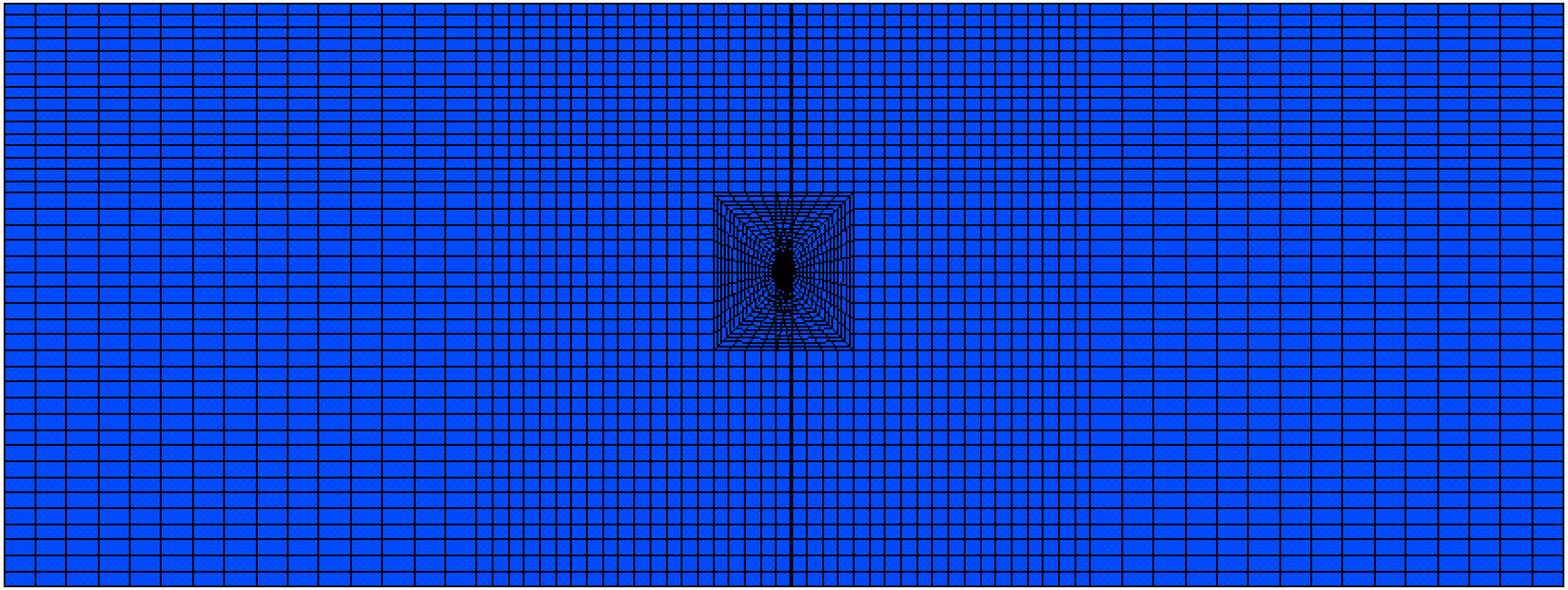


Buckling and Penetration

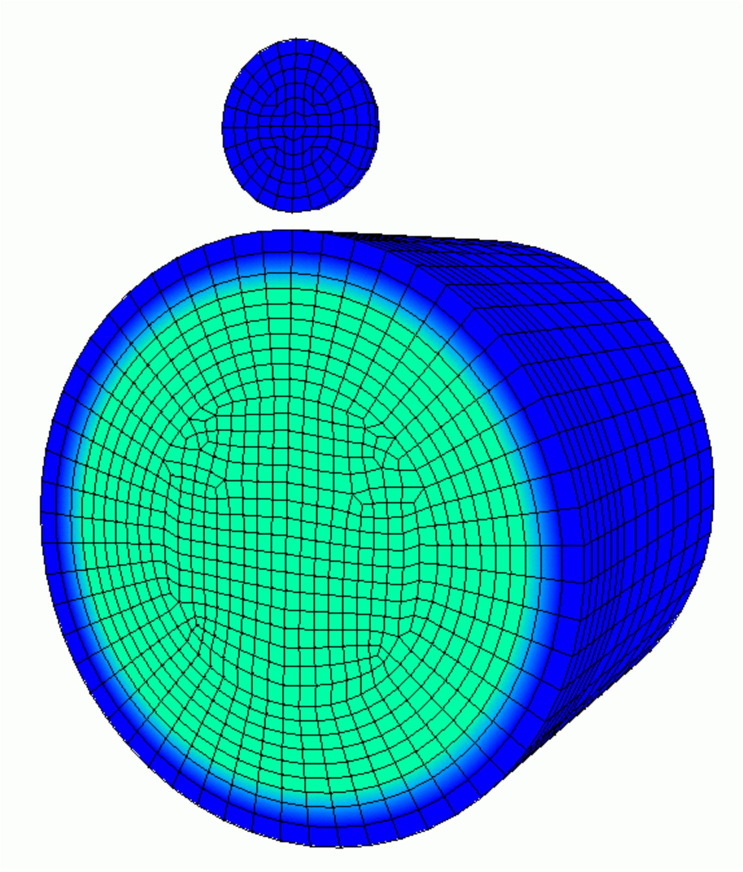




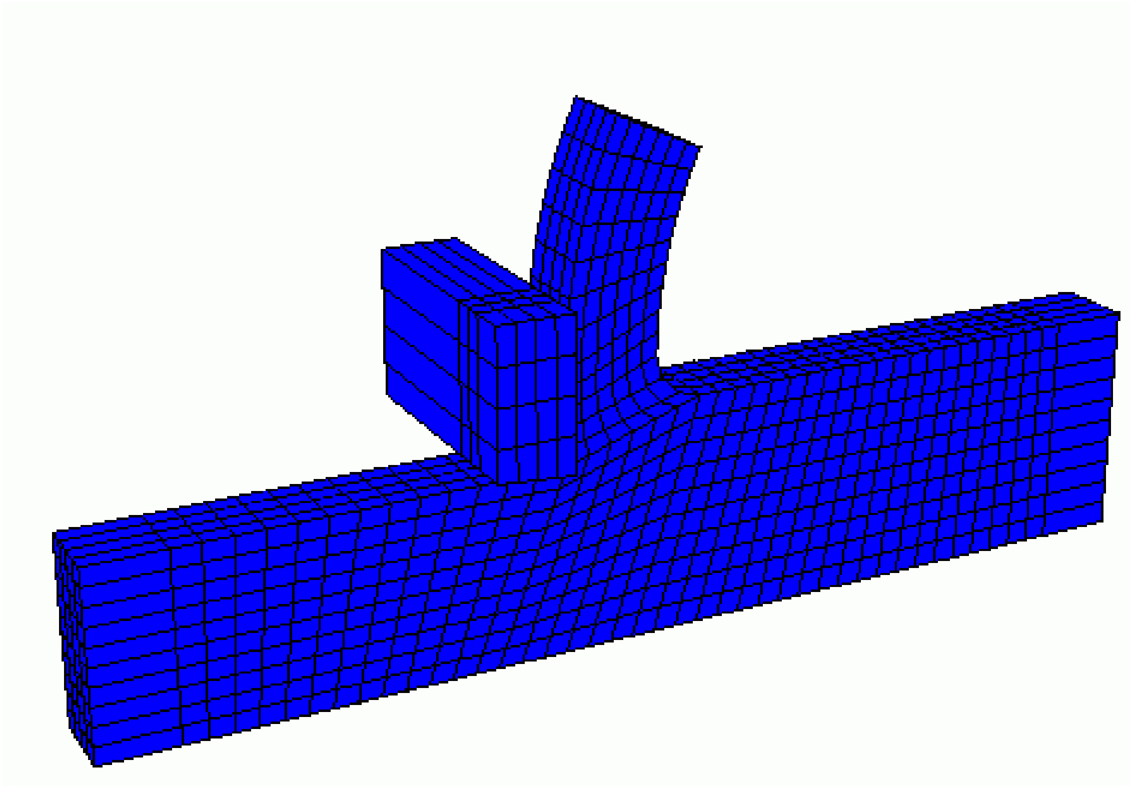
Underwater Explosion



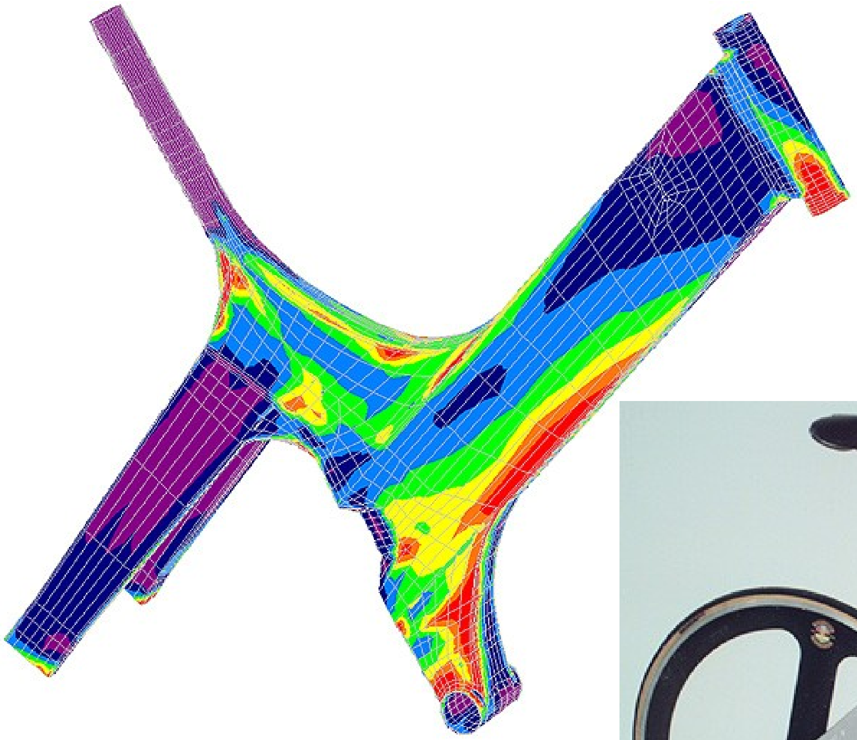
Missile Detonation (!)



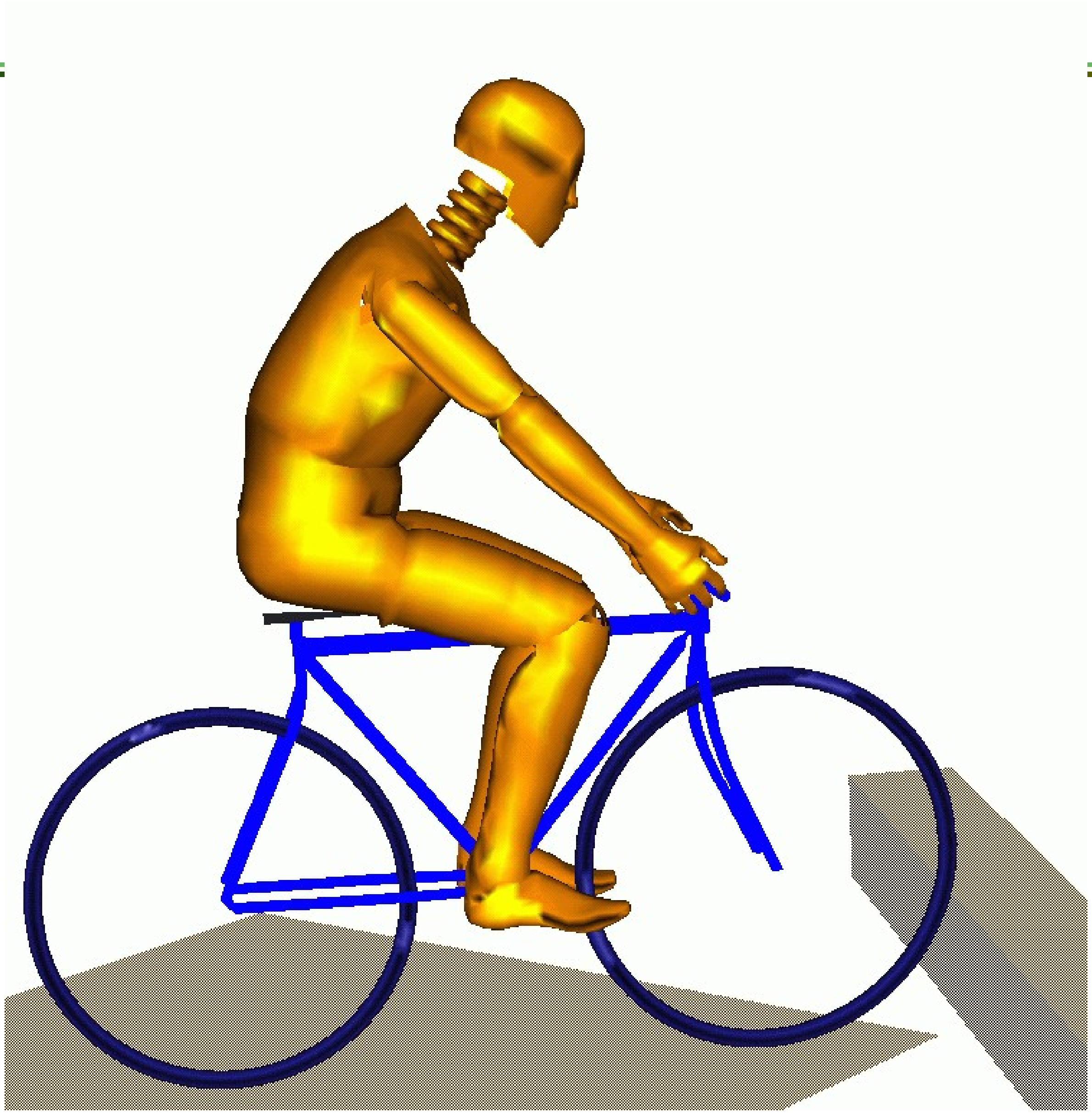
Milling



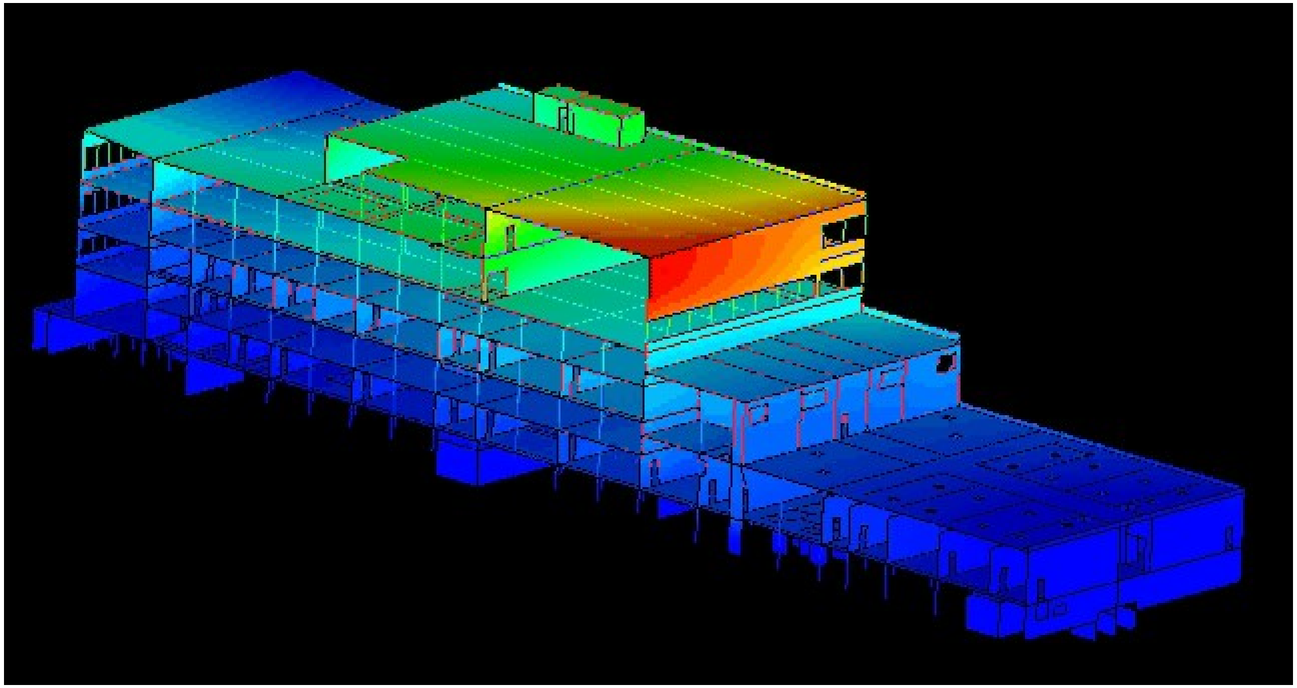
Bicycle frame design



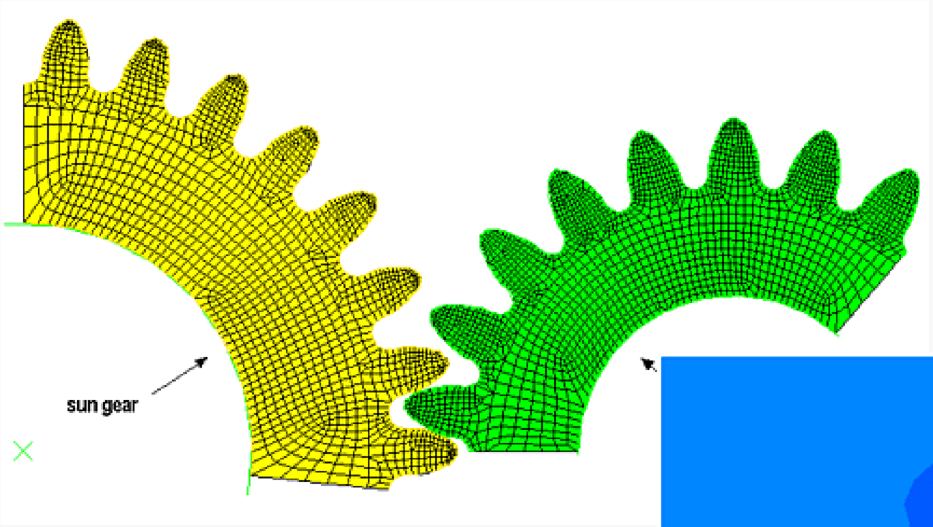
More Crashing

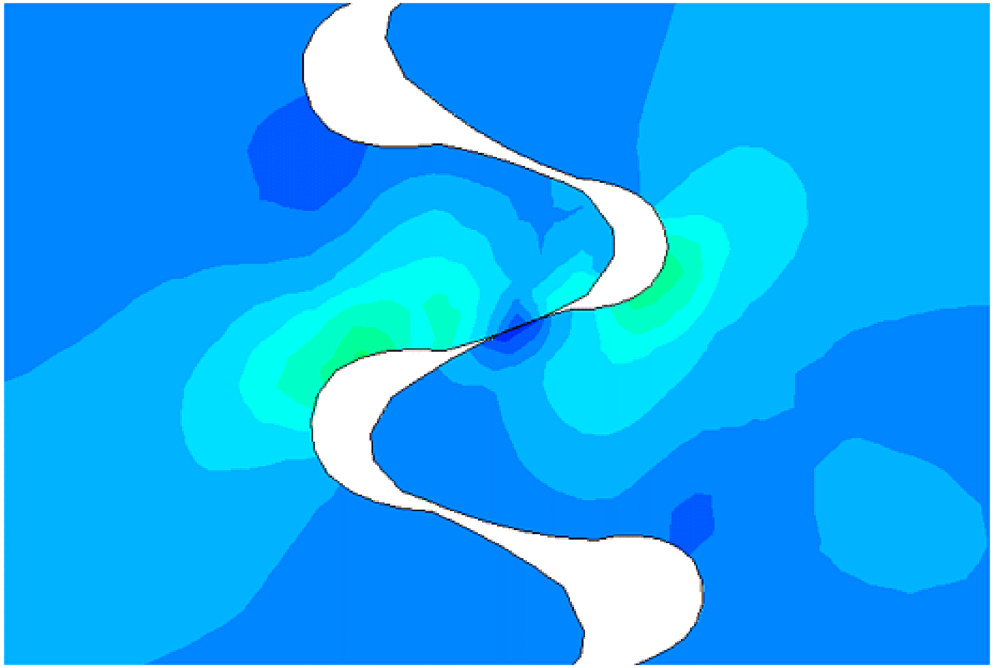


Earthquake Response

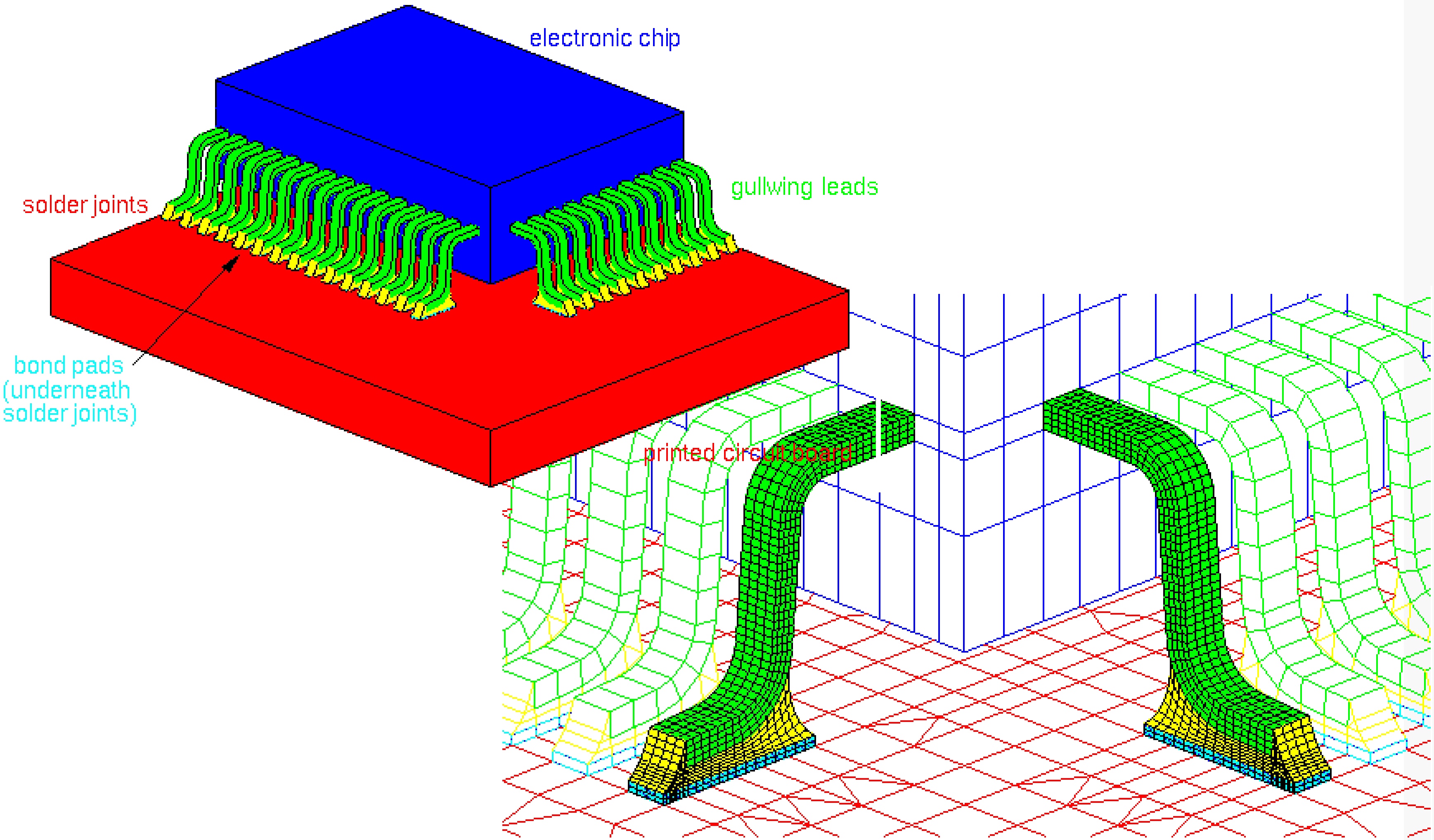


Gear Design



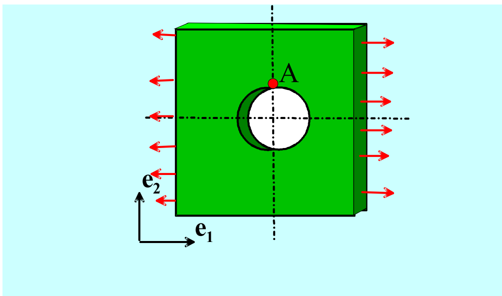


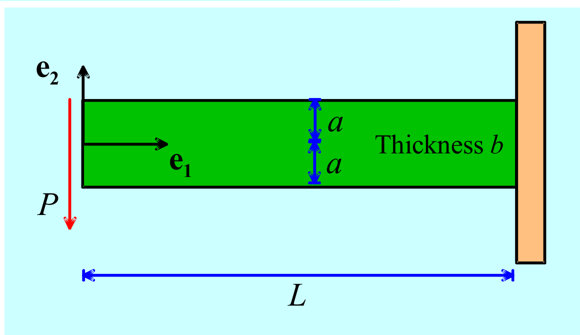
Stress in solder joints



Tools of the Trade

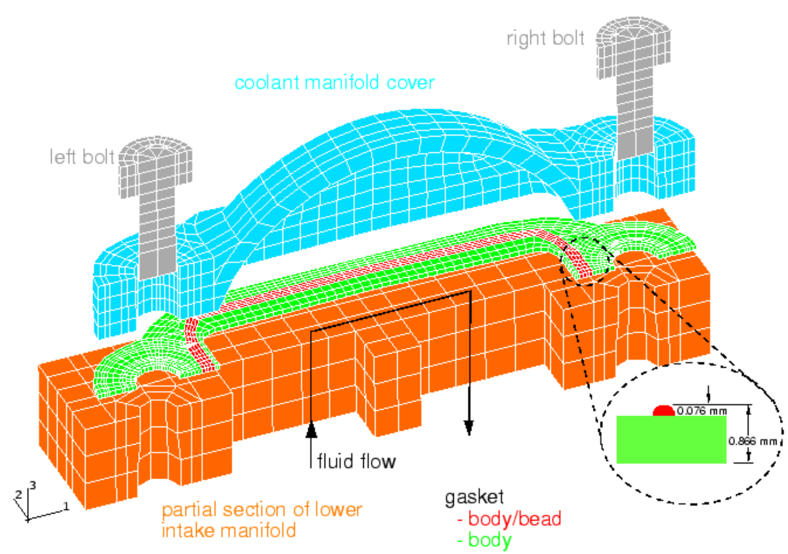
- Physical Intuition





- **Solutions to boundary value problems**

- **Finite Element Analysis**



Thank you