FEA and ANSYS

Overview

- In this chapter, we will define Finite Element Analysis and also give you an idea of ANSYS capabilities.
- Topics covered:

A. What is FEA?

- ***Finite Element Analysis*** **is a way to simulate loading conditions on a design and determine the design's response to those conditions.**
- **The design is modeled using discrete building blocks called *elements*.**
  - **Each element has exact equations that describe how it responds to a certain load.**
  - **The "sum" of the response of all elements in the model gives the total response of the design.**
  - **The elements have a finite number of unknowns, hence the name *finite elements*.**

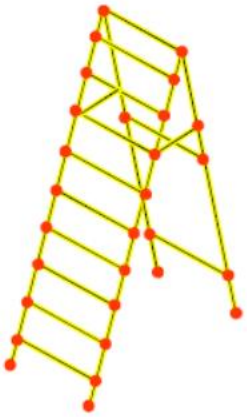
Historical Note

- **The finite element method of structural analysis was created by academic and industrial researchers during the 1950s and 1960s.**
- **The underlying theory is over 100 years old, and was the basis for pen-and-paper calculations in the evaluation of suspension bridges and steam boilers.**

...What is FEA?

- The finite element model, which has a *finite* number of unknowns, can only *approximate* the response of the physical system, which has *infinite* unknowns.
  - So the question arises: *How good is the approximation?*
  - Unfortunately, there is no easy answer to this question. It depends entirely on what you are simulating and the tools you use for the simulation. We will, however, attempt to give you guidelines throughout this training course.

Physical System



F.E. Model

FEA and ANSYS

...What is FEA?

Why is FEA needed?

- To reduce the amount of prototype testing
  - Computer simulation allows multiple “what-if” scenarios to be tested quickly and effectively.
- To simulate designs that are not suitable for prototype testing
  - Example: Surgical implants, such as an artificial knee
- The bottom line:
  - Cost savings
  - Time savings… reduce time to market!
  - Create more reliable, better-quality designs

B. About ANSYS

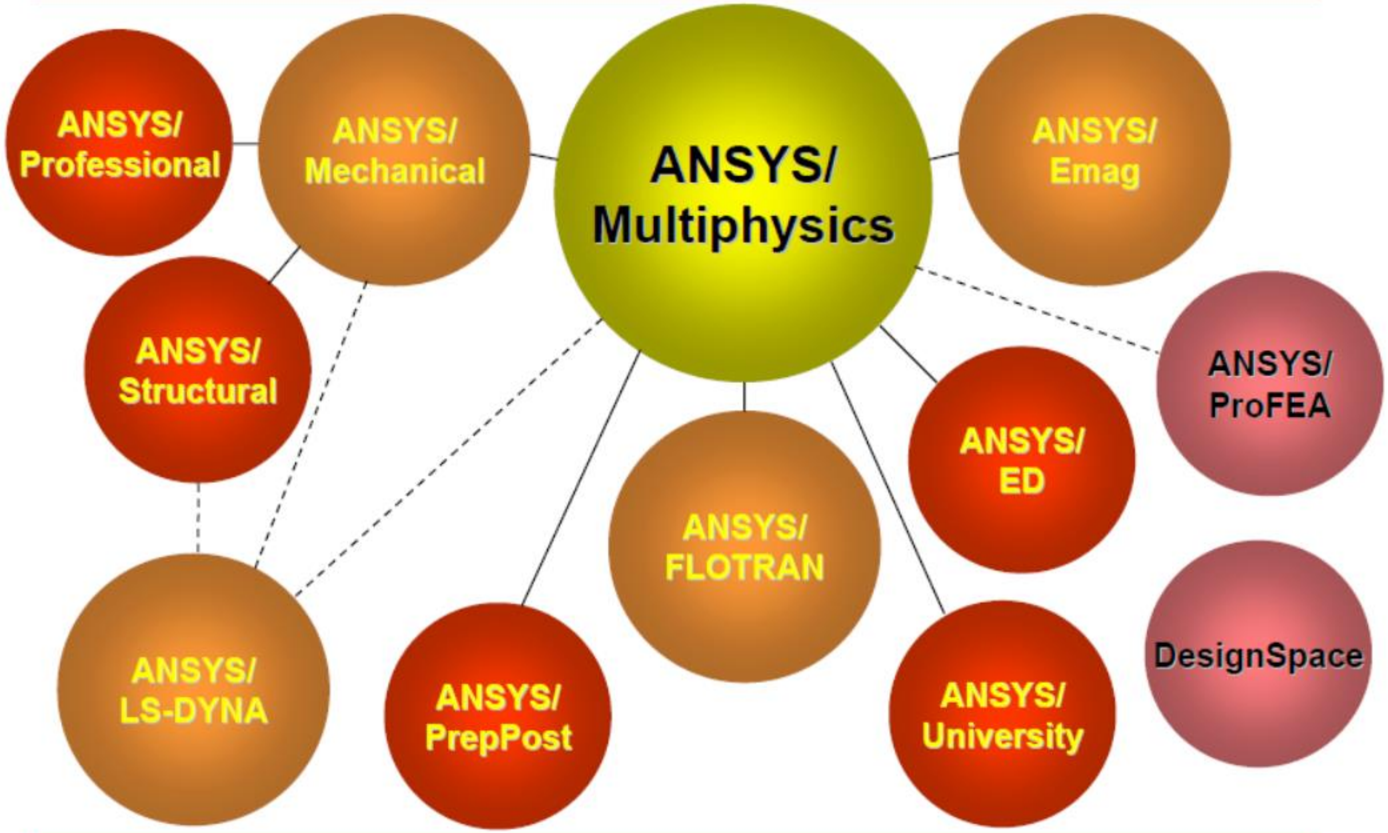
- ANSYS is a complete FEA software package used by engineers worldwide in virtually all fields of engineering:
  - Structural
  - Thermal
  - Fluid, including CFD (Computational Fluid Dynamics)
  - Electrical / Electrostatics
  - Electromagnetics
- A partial list of industries in which ANSYS is used:
  - Aerospace
  - Automotive
  - Biomedical
  - Bridges & Buildings
  - Electronics & Appliances
  - Heavy Equipment & Machinery
  - MEMS - Micro Electromechanical Systems
  - Sporting Goods

...About ANSYS

- **ANSYS/Multiphysics is the flagship ANSYS product which includes all capabilities in all engineering disciplines.**
- **There are three main component products derived from ANSYS/Multiphysics:**
  - **ANSYS/Mechanical - structural & thermal capabilities**
  - **ANSYS/Emag - electromagnetics**
  - **ANSYS/FLOTRAN - CFD capabilities**
- **Other product lines:**
  - **ANSYS/LS-DYNA - for highly nonlinear structural problems**
  - **DesignSpace - an easy-to-use design and analysis tool meant for quick analysis within the CAD environment**
  - **ANSYS/ProFEA - for ANSYS analysis & design optimization within Pro/ENGINEER**

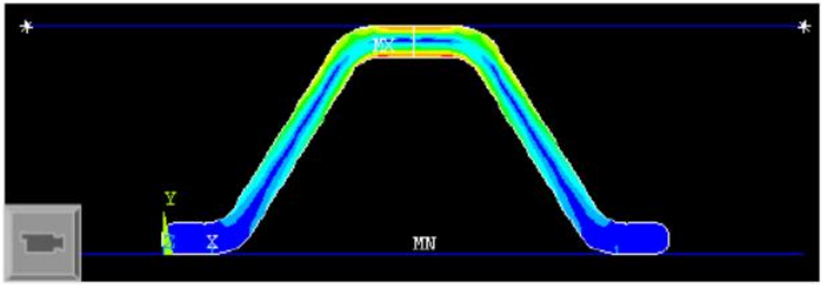
FEA and ANSYS

…About ANSYS



Structural Analysis

- **Structural analysis is used to determine deformations, strains, stresses, and reaction forces.**
- **Static analysis**
  - **Used for static loading conditions.**
  - **Nonlinear behavior such as large deflections, large strain, contact, plasticity, hyperelasticity, and creep can be simulated.**

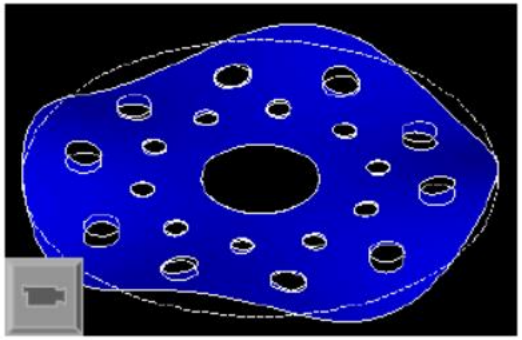


Hyperelastic Seal

FEA and ANSYS - About ANSYS

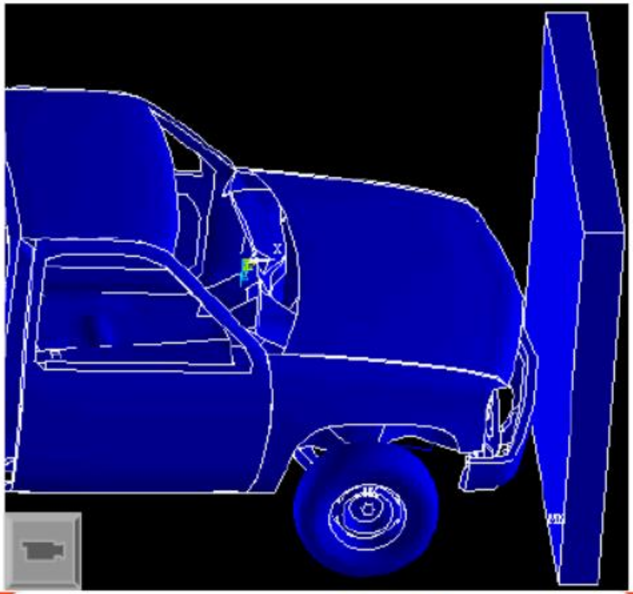
…Structural Analysis

- **Dynamic analysis**
  - **Includes mass and damping effects.**
  - **Modal analysis calculates natural frequencies and mode shapes.**
  - **Harmonic analysis determines a structure's response to sinusoidal loads of known amplitude and frequency.**
  - **Transient Dynamic analysis determines a structure's response to time-varying loads and can include nonlinear behavior.**
- **Other structural capabilities**
  - **Spectrum analysis**
  - **Random vibrations**
  - **Eigenvalue buckling**
  - **Substructuring, submodeling**



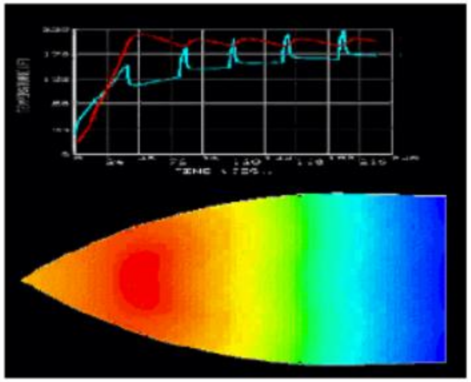
…Structural Analysis

- **Explicit Dynamics with ANSYS/LS-DYNA**
  - **Intended for very large deformation simulations where inertia forces are dominant.**
  - **Used to simulate impact, crushing, rapid forming, etc.**



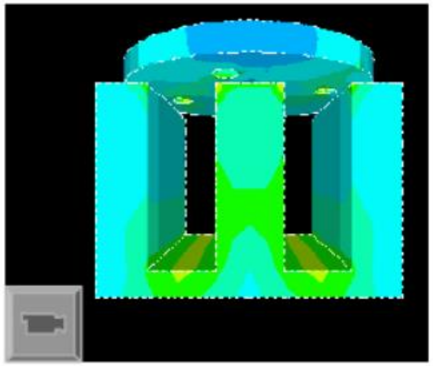
Thermal Analysis

- **Thermal analysis is used to determine the temperature distribution in an object. Other quantities of interest include amount of heat lost or gained, thermal gradients, and thermal flux.**
- **All three primary heat transfer modes can be simulated: conduction, convection, radiation.**
- **<u>Steady-State</u>**
  - **Time-dependent effects are ignored.**
- **<u>Transient</u>**
  - **To determine temperatures, etc. as a function of time.**
  - **Allows phase change (melting or freezing) to be simulated.**



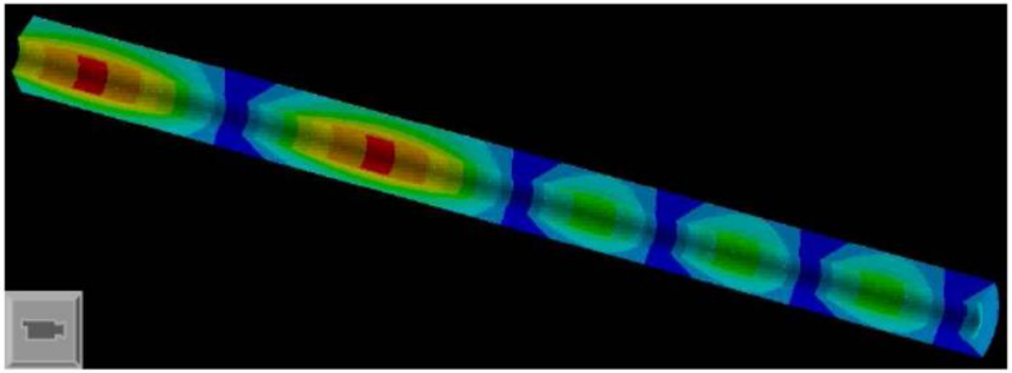
Electromagnetics

- Electromagnetic analysis is used to calculate magnetic fields in electromagnetic devices.
- Static and low-frequency electromagnetics
  - To simulate devices operating with DC power sources, low-frequency AC, or low-frequency transient signals.
  - Example: solenoid actuators, motors, transformers
  - Quantities of interest include magnetic flux density, field intensity, magnetic forces and torques, impedance, inductance, eddy currents, power loss, and flux leakage.



...Electromagnetics

- <u>High-frequency</u> electromagnetics
  - To simulate devices with propagating electromagnetic waves.
  - Example: microwave and RF passive components, waveguides, coaxial connectors
  - Quantities of interest include S-parameters, Q-factor, Return loss, dielectric and conducting losses, and electric and magnetic fields.



Electric field (EFSUM) in a coaxial cable

...Electromagnetics

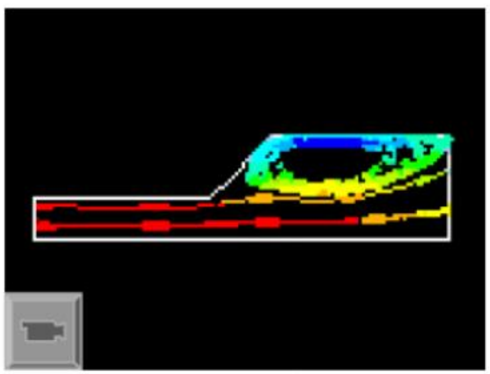
- **Electrostatics**
  - To calculate the electric field from voltage or charge excitation.
  - Example: High voltage devices, micro-electromechanical systems (MEMS), transmission lines
  - Typical quantities of interest are electric field strength and capacitance.
- **Current Conduction**
  - To calculate current in a conductor from an applied voltage
- **Circuit Coupling**
  - To couple electric circuits with electromagnetic devices

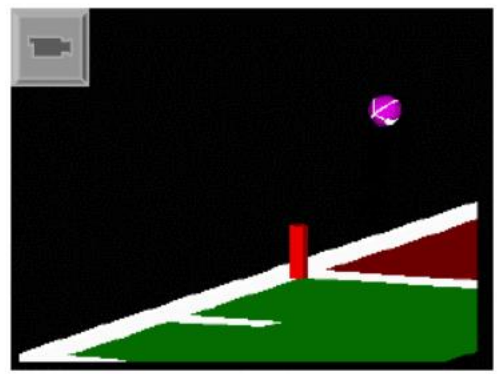
...Electromagnetics

- Types of electromagnetic analysis:
  - Static analysis calculates magnetic fields due to direct current (DC) or permanent magnets.
  - Harmonic analysis calculates magnetic fields due to alternating current (AC).
  - Transient analysis is used for time-varying magnetic fields.

Fluid Analysis

- <u>**Computational Fluid Dynamics (CFD)**</u>
  - **To determine the flow distributions and temperatures in a fluid.**
  - **ANSYS/FLOTRAN can simulate laminar and turbulent flow, compressible and incompressible flow, and multiple species.**
  - **Applications: aerospace, electronic packaging, automotive design**
  - **Typical quantities of interest are velocities, pressures, temperatures, and film coefficients.**





...Fluid Analysis

- **Acoustics**
  - To simulate the interaction between a fluid medium and the surrounding solid.
  - Example: speakers, automobile interiors, sonars
  - Typical quantities of interest are pressure distribution, displacements, and natural frequencies.
- **Contained-Fluid Analysis**
  - To simulate the effects of a contained, non-flowing fluid and calculate hydrostatic pressures due to sloshing.
  - Example: oil tankers, other liquid containers
- **Heat and Mass Transport**
  - A one-dimensional element is used to calculate the heat generated by mass transport between two points, such as in a pipe.

Coupled-Field Analysis

- Coupled-Field Analysis considers the mutual interaction between two or more fields. The fact that each field depends upon another makes it impossible to solve each separately, therefore you need a program that can solve both physics problems by combining them.
- Examples:
  - Thermal-stress analysis
  - Piezoelectrics (electric & structural)
  - Acoustics (fluid & structural)
  - Thermal-electric analysis
  - Induction heating (magnetic and thermal)
  - Electrostatic-structural analysis

Deflection of a bi-metal bar due to heating

THE END OF LECTURE TWO