NEW YORK CITY COLLEGE OF TECHNOLOGY
CITY TECH

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Introduction to Finite Element Analysis

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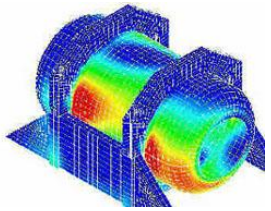
Outline

- Lecture (8:00-9:00am)
  - What is Finite Element Analysis (FEA)?
  - How Does FEA work?
  - How can we apply FEA to Architecture/Engineering?
  - How can we use results of FEA?
- Computer lab (9:00-10:30am)
  - Video
  - Simple tutorials

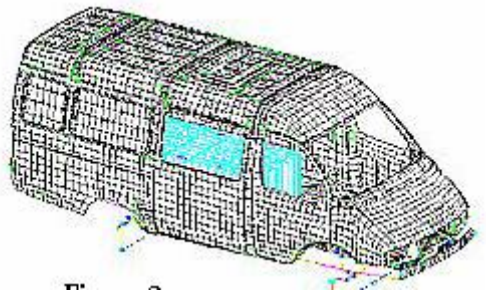
What is Finite Element Analysis (FEA)?

- Finite Element Analysis (FEA) was first developed in 1943 by R. Courant.
- FEA consists of a computer model of a material or design that is stressed and analyzed for specific results.
- It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction.
- Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition.
- https://www.youtube.com/watch?v=lrpj3cZrKn4



How Does FEA work?

- FEA uses a complex system of points called nodes which make a grid called a mesh. This mesh is programmed to contain the material and structural properties which define how the structure will react to certain loading conditions.
- Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of a particular area. Regions which will receive large amounts of stress usually have a higher node density than those which experience little or no stress.
- Points of interest may consist of: fracture point of previously tested material, fillets, corners, complex detail, and high stress areas. The mesh acts like a spider web in that from each node, there extends a mesh element to each of the adjacent nodes. This web of vectors is what carries the material properties to the object, creating many elements.

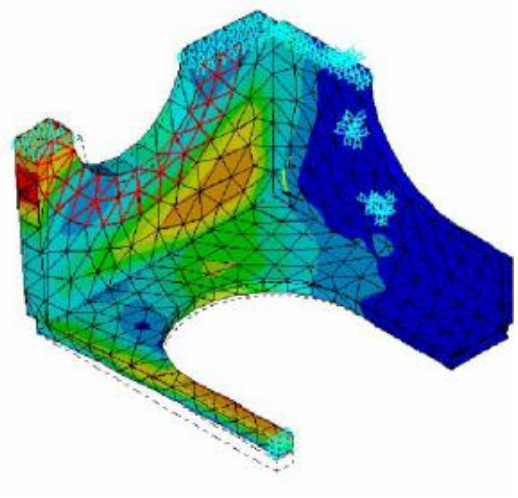


How Does FEA work?

- A wide range of objective functions (variables within the system) are available for minimization or maximization:
  - Mass, volume, Temperature
  - Strain energy, stress strain
  - Force, displacement, velocity, acceleration
  - Synthetic (User defined)

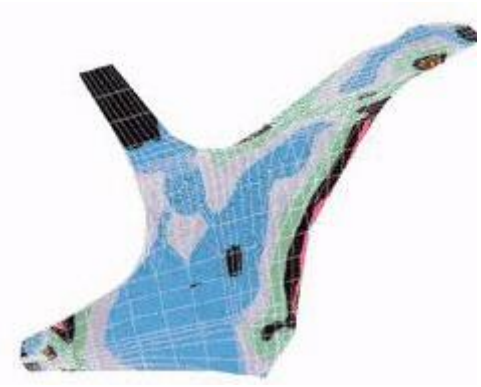
- There are multiple loading conditions which may be applied to a system. Next to Figure 3, some examples are shown:
  - Point, pressure, thermal, gravity, and centrifugal static loads
  - Thermal loads from solution of heat transfer analysis
  - Enforced displacements
  - Heat flux and convection
  - Point, pressure and gravity dynamic loads

- Each FEA program may come with an element library, or one is constructed over time. Some sample elements are:
  - Rod elements
  - Beam elements
  - Plate/Shell/Composite elements
  - Shear panel
  - Solid elements
  - Spring elements
  - Mass elements
  - Rigid elements
  - Viscous damping elements



How can we apply FEA to Architecture/Engineering?

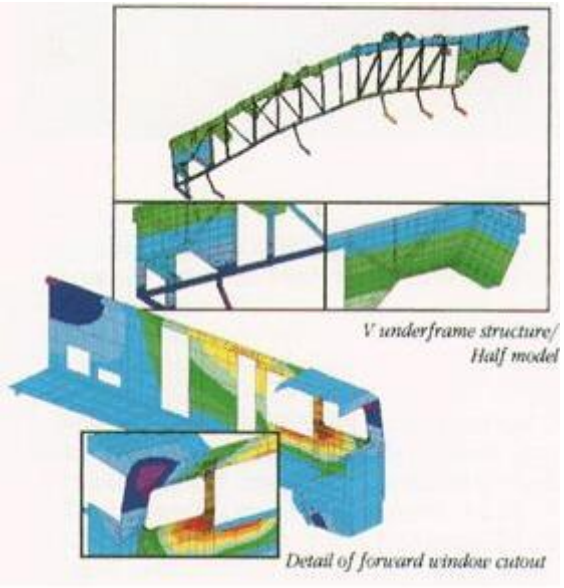
- **Structural** analysis consists of linear and non-linear models. Linear models use simple parameters and assume that the material is not plastically deformed. Non-linear models consist of stressing the material past its elastic capabilities. The stresses in the material then vary with the amount of deformation.



- **Vibrational** analysis is used to test a material against random vibrations, shock, and impact. Each of these incidences may act on the natural vibrational frequency of the material which, in turn, may cause resonance and subsequent failure.

- **Fatigue** analysis helps designers to predict the life of a material or structure by showing the effects of cyclic loading on the specimen. Such analysis can show the areas where crack propagation is most likely to occur. Failure due to fatigue may also show the damage tolerance of the material.

- **Heat Transfer** analysis models the conductivity or thermal fluid dynamics of the material or structure. This may consist of a steady-state or transient transfer. Steady-state transfer refers to constant thermal properties in the material that yield linear heat diffusion.



How can we use results of FEA?

- FEA has become a solution to the task of predicting failure due to unknown stresses by showing problem areas in a material and allowing designers to see all of the theoretical stresses within.
- This method of product design and testing is far superior to the manufacturing costs which would accrue if each sample was actually built and tested.

Keywords

- **Fatigue Life:** The number of cycles the will cause failure at a certain stress level
- **Node:** Points at which different elements are jointed together; nodes are the locations where values of unknowns (usually displacements) are to be approximated.
- **Mesh:** The grid of a finite element system

Computer Lab: Videos

- https://www.youtube.com/watch?v=LOa3MXH9P4c
- https://www.youtube.com/watch?v=KOcI2eQ036M

Computer Lab: Tutorial

- Let’s do together.