FINITE ELEMENT ANALYSIS

FEA took shape in 1959 - 1960 in the aeronautical industry. Now it is widely used in automobile industry to reduce weight and also to improve fuel efficiency.

The FE method, combines several mathematical concepts to produce a system of linear or non-linear equations. FEA, or finite element analysis, is a technique for predicting the response of structures and materials to environmental factors such as forces, heat and vibration The basic concept used is that the structure to be analyzed is considered as a assembly of discrete pieces called elements connected at nodes. These elements is nothing but a geometrically simplified representation of a small part of the physical structure.

Boundary value problems:

The best way to solve any physical problem governed by a differential equation is to obtain an analytical solution. However, this may be not possible under the following circumstances.

1. The region under consideration may be so irregular that it is mathematically impossible to describe the boundary.
2. Equation may have non-linear terms,
3. The configuration may be composed of several different materials whose regions are mathematically difficult to describe.

A numerical method can be used to obtain an approximate solution when an analytical solution cannot be developed. All numerical solutions produce values at discrete points for one set of independent parameters. These numerical methods can be grouped under the following three categories.

- The finite different method.
- Variational method and
- The methods that weight a residual.

Steps in FEA:

1. Make finite element approximation or the FE model.
2. The corner points are called nodes and the elements are numbered. The nodes and element together represents the approximate FE model of the part.
3. Using the principle of minimum energy a displacement function is chosen in an element, to obtain the relation between nodal force and displacement.
4. A set of algebraic equations are formed, because equilibrium is posed at nodes and unknowns are the nodal displacement.
5. The stress and strain for each element is determined from nodal displacement.

The above steps could be summarized as given below.

- Define nodes and elements.
- For individual stiffness matrix for each element.
- Assemble the stiffness matrix and analyze based on boundary condition.

- Modify the Problem (Next Iteration).
- Repeat Until optimization.

Basic element shapes:

The choice of element is decided by geometry of the body and a number of independent spatial co-ordinates are necessary to describe them. When the geometry , material properties can be described in terms of only one spatial co-ordinate then 1-D elements are used. It is generally shown as a line segment. If two independent spatial co-ordinates then we can use 2-Dimensional elements. Some problems which are actually three-dimensionally can be described by only one or two independent co-ordinates. Such problems can be idealized by using an axi-symmetric or ring type of elements.

For discretization of problems involving curved geometries, finite elements with curved boundaries are useful. The ability to model curved boundaries has been made possible by the addition of mid side nodes. Finite element with straight sides are known as linear elements. While those with curved sides are called higher order elements.

Number of elements:

the number of elements to be chosen for idealization is related to the desired accuracy, size of elements, and the number of degrees of freedom involved. For any given problem, there will be a certain number of elements beyond which the accuracy cannot be improved by any significant amount.

Types of Analysis:

1. Static and Dynamic Analysis:

FEA is most commonly used in structural and solid mechanics applications for calculating stresses and displacements. These are often critical to the performance of the hardware and can be used to predict failures. Response is static if load is stead (static). When load varies with time (Dynamic), the dynamic force produces velocities and acceleration which produces appreciable variation in displacement and stress. These are computed with varying time and the response history is called transient response analysis.

2. Linear and Non-Linear Analysis:

If the properties of the structure such as stiffness matrix remains constant during entire analysis the analysis is linear. Else it is Non-Linear (E.g.. Large displacement in structure)

3. Thermal Analysis:

FEA can be used for thermal analyses to evaluate the temperature distribution, and stresses resulting from uneven heating or rapid temperature changes. Thermal analyses may include convection, conduction, radiation, steady-state, and transient analyses.

4. Fluid Flow analysis :

FEA provides insight into complex transient and turbulent flow fields. It allows analysis and optimization of component geometry for efficient fluid flow, as well as allowing users to view velocity, pressure and thermal conditions inherent in the modeled flow fields.

5. Field Analysis:

Electromagnetic compatibility and electromagnetic interference can be important in the analyses of many devices. FEA methods allows to model the electromagnetic phenomenon.

6. Motion simulation :

Motion simulation allows users to test and verify that their designs will work before physical prototypes are built. It tests the function of mechanisms virtually, resulting in quantitative reductions in physical prototyping costs and reduced product development time. In addition, it provides qualitative benefits such as the ability to consider more designs, risk reduction, and the availability of valuable information early in the design process.

Stiffness Matrix:

It is nothing but a collection of terms called as influence coefficients. The influence coefficient relating a force at a point to a set of displacements are called as Stiffness Matrix.

Mesh Generation:

It is nothing but discrimination of the given structure into nodes and elements. The shape of the elements should not be irregular and as far as possible resemble standard shapes like Triangle, Square Etc.

Source:

http://www.oocities.org/venkatej/mech/fem.html