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Finite Element Analysis (F E A) - An Insight

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INTRODUCTION

Finite Element Analysis is a numerical method of structure analysis based on principle of dividing an infinite structure into a finite number of small elements connects each other at the corner points or nodes. It is a means of discretizing a continuous structure into sub-domains called Finite Elements. Essentially an attempt at simulating a physical object and analysing it's behaviour when subjected to various circumstances. This is a well-sophisticated engineering tool, which has been used extensively in design optimization and structural analysis. It is one of the most significant developments in the history of computational methods. This method is originated in aerospace industry to study stresses in complex airframe structures. Modern version of finite element method first used in engineering by Turner et al. The term finite element was coined by Argyris and Clough in 1960. First introduced to the dental arena in the 1970's and growth model was documented by MOSS in 1980.

ADVANTAGES

1. Accuracy
2. Reproducibility
3. No usage of materials
4. Generation of intra-material results

Basic steps involved in FEA

a) Pre-processing
b) Processing
c) Post-processing

Pre-processing

Pre-Processing basically involves modelling of the structure being studied. It is the most crucial step in the finite element analysis. In Pre-processing, the structure being studied is discretised into smaller units termed the elements. Each element is free to get displaced in all the three planes of space.

The element co-ordinates (x,y,z) can be either
a) Global Co-ordinate system or
b) The Local Co-ordinate system

Various categories of elements exist. Examples are

□ Shell element
□ Beam element
□ Truss element etc.

Newer possibilities of modelling of complex structures icludes
a) 3-D CT scanning
b) 3-D Laser scanner
c) Voxel modelling

These elements are connected at certain points termed 'Nodes'. The joining of elements into nodes and eliminating duplicate nodes is termed as "Meshing".

The mesh size is a crucial determinant of the accuracy of the result. However, it is inversely related to the time involved in the analysis. The meshed model is now a free-floating body. To simulate the exact structure, the material properties are assigned and boundary conditions enforced.

MATERIAL PROPERTIES

The minimum properties to be assigned are

a) The Modulus of elasticity

b) Poisson's ratio.

Modulus of elasticity (Young's modulus) refers to the stiffness of the material within its elastic range.

Stress

E = ------------

Strain

Modulus of elasticity of dental structures

a) Enamel - 65 GPa

b) Dentin - 15 GPa

c) Alveolar bone - 10 GPa

d) Periodontal ligament - 0.05 GPa

Poisson's ratio denotes the strain imposed on the material relative to the axis of the load applied.

Strain perpendicular to the force

P = ---

Strain parallel to the force

Poisson's ratios for dental structures

a) Enamel - 0.32

b) Dentin - 0.28

c) Alveolar bone - 0.33

d) Periodontal ligament - 0.3

After assigning the material properties, the material is constrained identical to the real situation. The freedom of the body to be displaced is termed as the "degrees of freedom". Each element has six degrees of freedom. The final step in Pre-processing is the application of loads. These can be either force or moments and be directed at any node in all the three planes of space.

PROCESSING

a) Solving of differential equations.

b) Assemblage into matrices

c) Summation of the matrix equations

The equation for the simplest linear static analysis is represented as

$$[F] = \{K\}\{u\}$$

The non-linear analysis is solved usually by what is termed as the "Newton-Raphson method".

POST-PROCESSING

a) Graphical output

b) Numerical output

c) Animated output