Finite Elements Method

(Spring 2026)

Instructor: H. Golpira

Course Description and Objectives

The FEM is a numerical method based on algebraic equations to yield approximate values of the unknowns. This modeling approach divides a body into elements formulated in equations and combined to obtain a solution for the whole structure. The displacement at each node and the stress within each element making up the structure under loads make the model well-suited for computational design of machine elements. In this course, we discuss the stiffness equation and its application to truss and beam solving problems. These provide students with enough knowledge on FEM to deal with other engineering problems, i.e., heat transfer.

Topics Covered

Part I: Instructor: H. Golpira

1. Global stiffness equation
2. Stiffness matrix for a spring element
3. Direct stiffness method (superposition)
4. Boundary conditions (homogeneous and nonhomogeneous)
5. Potential energy in spring elements
6. Stiffness matrix for a bar element in local coordinates
7. Displacement function 1D bar element
8. Global stiffness matrix for a bar in the plane
9. Computation of stress for a bar in the plane
10. Example: solving a problem on a plane truss
11. Computer program for a 3D truss
12. Transformation and stiffness matrix for a bar in 3D space
13. Comparison of the FEM solution to the exact solution for a bar
14. Galerkin residual method in the 1D bar element equation
15. Beam stiffness matrix (Euler-Bernoulli theory)
16. Example: beam analysis using the direct stiffness method
17. Distributed loading

18. FEM against the exact solution

Homework/Assignments

The course assignments will be performed throughout the semester.

1. Homework 1: spring problem
2. Homework 2: truss problem
3. Homework 3: beam problem

References

[1]

Grading

- Homework: 20%
- Final Exam: 50%
- Final project: 30%

Final Project

Each student must analyze a beam computationally in ANSYS based on his/her interest. This will give students a chance to deepen their knowledge in a specific area. You will provide a detailed written report and simulation files. Details will be discussed in the class.