Course-Plan

School : School of Engineering
Department : Mechanical Engineering
Course Code : ME 510
Course Name : Engineering Design Laboratory

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1. Abstract

This is a core mechanical design laboratory course designed for the postgraduate students of Machine Design specialization. This course aims at solving engineering design problems numerically using different numerical tools. Students are introduced with the commercial finite element software package such as ANSYS and programming in MATLAB for numerical computation. A range of problems involving elasticity, elasto-plasticity and fracture mechanics are covered through examples with special emphasis on their applications. The course will also introduce the experimental methods for stress analysis in solids as well as the analysis of experimental data using different tools.

2. Objectives:

- To introduce with FEM packages like ANSYS for stress analysis of a certain class of engineering problems subjected to different kinds of loading.
- To provide a thorough understanding of programming with MATLAB to solve design problems numerically.
- To introduce with MATLAB Simulink.
- To provide a brief introduction of different experimental methods for stress analysis.
- To understand the significance of experimental data and their analysis.

3. Prerequisite of the course: Adv. Solid Mechanics, Mathematical Methods for Engineers.

4. Course Outline and Time Plan

Sl. No.	Topics	Contents	No. of classes (each of 2 hours duration)
1	Introduction to Computer-Aided Design and Analysis	a) Basic understanding of drafting, modeling of parts and assembly, meshing, application of boundary conditions, solution and post processing. b) Mesh sensitivity analysis. c) Solving a class of engineering design problems using finite element based package ANSYS and their comparison with the analytical solutions: • Stress analysis in beams subjected to transverse loads and moments whose vectorial direction is perpendicular to the axis of the beam (simply supported and cantilever type). • Stress analysis in simple truss structure. • Stress analysis of slender members subjected to combined loading (axial load, transverse load and torsion together). • A rectangular plate with a very small hole at the centre subjected to a tensile pull. • Mechanical bending of sheets. • Analysis of laser bending. • Analysis of plastic deformation of a metallic strip in rolling.	14

		• Analysis of elasto-plastic axisymmetric problems • Analysis of crack growth for an elliptical crack at the centre of a plate subjected to tension.	
2	Introduction to computational modelling	a) Introduction to MATLAB Programming: • Basics of MATLAB programming • Array operations in MATLAB • Loops and execution control • Working with files: Scripts and functions • Plotting and program output b) Numerical Differentiation and Integration: • Numerical Differentiation in single variable • Numerical differentiation: Higher derivatives • Differentiation in multiple variables • Newton-Cotes integration formulae • Multi-step application of Trapezoidal/Simpson's rule • MATLAB functions for integration c) Solving Linear Equations Using MATLAB d) Nonlinear Equations: • Nonlinear equations in single variable.	16

		• MATLAB function FZERO in single variable. • Fixed-point iteration in single variable. • Newton-Raphson in single variable. • MATLAB function FSOLVE in single and multiple variables. • Newton-Raphson in multiple variables. e) Example problems with specific application to engineering analysis of various structures and systems. f) Introduction to MATLAB Simulink.	
3	Experiments with Solids	a) Material properties. b) Experimental measurement of force, torque, stress, strain and displacements. c) Introduction to photoelasticity and strain gauge method. d) Investigation of the microstructure of materials. e) Introduction to digital image correlation for stress analysis.	6
4	Analysis of experimental data	a) Error analysis. b) Uncertainty analysis. c) Data reduction techniques. d) Statistical analysis of data. e) Probability distributions and curve fitting.	6
		Total	**42**

Textbooks

1. Wheeler, A.J. and Ganji, A.R., *Introduction to Engineering Experimentation* (Prentice Hall, 2003)
2. Chapman, S.J., *MATLAB Programming for Engineers* (Cengage Learning, 2007)

References

1. Munford, P., Normand, P., *Mastering Autodesk Inventor 2016 and Autodesk In-ventor LT 2016* (John Wiley Sons, 2016)
2. Kent, L.L.., *ANSYS Workbench Tutorial Release 14* (SDC Publications, 2012)
3. Doeblin, E.O., *Engineering Experimentation* (McGraw-Hill, 1995)
4. Chapra, S.C., Applied Numerical Methods with MATLAB for Engineering and Science, (McGraw-Hill Science, 2004).
5. MATLAB Handbook.

Suggested Additional Reading (Some problems will be solved from journal articles)

Sample articles from the journals:

- Kamal S.M., Analysis of residual stress in the rotational autofrettage of thick-walled disks, *ASME Journal of Pressure Vessel Technology*, 2018, 140(6), pp. 061402-1−061402-10.
- Kamal S.M., Dixit U.S., Roy A., Liu Q. and Silberschmidt V.V., Comparison of plane-stress, generalized-plane-strain and 3D FEM elastic-plastic analyses of thick-walled cylinders subjected to radial thermal gradient, *International Journal of Mechanical Sciences*,2017,131-132, pp. 744−752.
- Kamal S.M., Borsaikia A.C. and Dixit U.S., Experimental assessment of residual stresses induced by the thermal autofrettage of thick- walled cylinders, *Journal of Strain Analysis for Engineering Design*, 2016, 51(2), pp. 144–160.
- Kamal S.M. and Dixit U.S., Feasibility study of thermal autofrettage of thick-walled cylinders, *ASME Journal of Pressure Vessel Technology*, 2015, 137(6), pp. 061207-1−061207-18.
- Chetry A., Kamal S.M. and Mehta V.K., A numerical model for rotational autofrettage of disks based on von Mises yield criterion and its application in strengthening flanged disks used for joining high pressure pipelines, *International Journal of Applied Mechanics*, 2023, 15(03), pp. 2350022, DOI: 10.1142/S1758825123500229.

5. Evaluation Plan

Test No.	Marks	Duration (minutes)
Sessional Test I	10	-
Mid-Semester Examination	30	90
Sessional Test II	10	-
End-Semester Examination	50	120
Total	**100**	

All the tests will be held as per the schedule notified by the Controller of Examinations, Tezpur University.

6. Pedagogy:

Lectures, Hands on practical sessions on solving problems in ANSYS, MATLAB programming, Assignments, Group work.

7. Expected Outcome:

After completion of this laboratory course, students will be able to

CO1: use FEM packages like ANSYS for solving engineering problems ranging from basic to complex type.

CO2: write program in MATLAB to solve a class of engineering problems.

CO3: understand different experimental process and techniques for different experimental analysis.

CO4: analyze experimental data to conclude on their significance and basics of statistical tool.