Assignments

Personal work reported as a learning diary (50% of the course grade, submission by the end of the course to the Turnitin box, 16.10.2023 09:00)
The learning diary replaces the traditional exam in the course where group work -based assignments are used to test the application of theory to practice. The learning diary must be individual and reflect the learning with the focus:

- at the low-end to theory and relation to former and future studies,
- in the middle to main theories and their meaning in context of assignment and
- at the high-end to the open scientific literature on the subject.

The learning diary is returned by the end of the course to the Turnitin-box for a similarity and AI checks. Acceptable submission has similarity index less than 30%. For each of the 6 weeks describe:

Grade 1 (50%): Make brief notes of what you did and why with respect to the learning objectives of the week, the video lectures you watched, question hours participated, assignments done and any extra reading that helped your learning. Describe the relation to the former and future studies inside and outside this course.

Grade 2 (60%) Describe by words the main idea of the theoretical concept of the week. Expand this description with the mathematical description and prevailing assumptions.

Grade 3 (70%): Describe the theoretical concepts that were used in the assignment. Explain the main simplifications done and their benefits and weaknesses. Focus on the theoretical treatment, e.g. mathematics.

Grade 4 (80%): What was the core idea of the assumptions used with respect to the theory applied this week? Describe the validity of these in your assignment? What was the role of this week in the big picture of thin-walled structures (see written description and mathematics)?

Grade 5 (90%): Describe what topics from the lectures and assignments were used in the weekly article(s)?

The report should be a summary of the cumulative learning accumulated over the course. Focus on technical details and their connections between different assignments. **Note! Simply putting the reports together by Copy and Paste does not work**. You need to be able to explain your learning by your own words.

Week 1 specific guiding questions and articles:
How is thin-walled structure defined based on mathematics and physics? What is the role of the FEA in the analysis of thin-walled structures? What are the other issues we must consider? In case the loading is not known, how can you deal with this in design?

Bazant, Z.P. and Zhou, Y., "Why Did the World Trade Center Collapse?—Simple Analysis", Journal of Engineering Mechanics, 128(1), 2002, pp. 1-6.
Romanoff, J., Remes, H., Varsta, P. Reinaldo Goncalves, B., Lillemäe-Avi, I., Kõrgesaar, M., Jelovica, J. and Lönnbarga, S., "Limit state analyses in design of thin-walled marine structures - some aspects on length scales", Journal of Offshore Mechanics and Arctic Engineering, Vol. 142, June 2020, pp. 030801-1-8.

Week 2 specific guiding questions and articles:
How does the stiffness and compliance matrix is affected by the type of ply used? With which kind of fibers is the ply orthotropic and when isotropic? What is the difference between constant strain and constant stress assumptions? Why do we need both? How does von Karman strain affect the beam and plate responses and why, give mathematical reasoning?

Hill, R., "Elastic Properties of Reinforced Solids: Some Theoretical Principles", Journal of Mechanics and Physics of Solids, 11, 1963, pp. 357-372.
Sun, C.T. and Vaidya, R.S., "Prediction of Composite Properties from Representative Volume Element", Composites Science and Technology, 56(1), 1996, pp. 171-179.

Week 3 specific guiding questions and articles:
Why do we have different structural theories? What is the difference in CLT, FSDT and TSDT in terms of assumptions and mathematics? What are the physical and mathematical differences between plates and shells?

Reddy, J.N., and Averill, R.C., "Advances in the Modeling of Laminated Plates", Computing Systems in Engineering, 2(5/6): 1991, pp. 541-555.
Carrera, E., "Historical review of Zig-Zag theories for multilayered plates and shells", Applied Mechanics Reviews, 56(3), 2003, pp. 287-308.

Week 4 specific guiding questions and articles:
Under which conditions we can analyze a plate response with the beam theory very accurately? How can we account the shear lag in flanges of a beam by using the so-called effective breadth? Why and how we can model the stiffened panel response by using a laminate theory?

Avi, E., Lillemäe, I., Niemelä, A. and Romanoff, J., "Equivalent Shell Element for Ship Structural Design", Ships and Offshore Structures, Vol. 10, No. 3, 2015, pp. 229-255.
Paik, J.K., "Some recent advances in the concepts of plate-effectiveness evaluation", Thin-Walled Structures, 46, 2008, pp. 1035–1046.

Week 5 specific guiding questions and articles:
What is the challenge on the fatigue analysis of a thin-walled structure exposed to random loading form nature? What issues affect the type of fatigue analysis you need to perform in thin-walled structure? Why do the eigenfrequencies change if you have different kinematical constrains in your structural model? How can the eigen frequencies and modes be used to assess the fatigue life?

Loukas, A., Romanoff, J., Niemelä, A., Remes, H., and Avi, E., "Free vibration by length-scale separation and inertia-induced interaction - application to large thin- walled structures", Mechanics of Advanced Materials and Structures, 2023 DOI: 10.1080/15376494.2023.2029981.
Remes, H., Romanoff, J., Lillemäe, I., Frank, D., Lönnbarga, S., Lehto, P. and Varsta, P, "Factors affecting the fatigue strength of thin plates in large structures", International Journal of Fatigue, 101, 2017, pp. 397-407.

Week 6 specific guiding questions and articles:
What does it mean when we talk about bifurcation buckling and how does that relate to the reality? How can you assess the progressive failure of a thin-walled structure? In what sequence should the structure fail so that the process is stable?

Bazant, Z., "Structural Stability", International Journal of Solids and Structures, 37, 2000, pp. 55-67.

Byklum, E. and Amdahl, J., "A simplified method for elastic large deflection analysis of plates and stiffened panels due to local buckling", Thin-Walled Structures, 40, 2002, pp. 925-953.

Group work (50% of the course grade)
The course follows Problem-Based-Learning concepts and utilizes a living document that incrementally form larger entity that covers synthesis of the techniques learned during the course. Each week has specific assignment which supports the overall analysis of thin-walled structures. The weekly reports should contain a short description (max 6 pages of main text + unlimited appendixes) of the:

1) Introduction to the weekly assignment with review to relevant literature (books, scientific and technical articles),
2) Methods used to solve the assignment including their strengths and limitations,
3) Main Results including critical review of the quality of them,
4) Discussion and reflection to the overall design task and related sub-questions
5) The roles and time allocation of group members in table format (lectures, assignment, self-study of literature, meetings). The weekly group assignments are:

Assignment 1. Modelling thin-walled structures by FEM
Given: 04.09.2023
Due: 11.09.2023 09:00

The idea of the assignment is to introduce you to the modelling of thin-walled structures by FEM and create a reference model that we can use to compare the results of the following weeks.

You need to create a shell element based finite element model of a stiffened panel with a software you know (FEMAP, Abaqus, Ansys, etc). You need solve it and interpret the results (stresses and deflections as contour plots and xy-plots of a selected section of the panel). In case you have your own design, feel free to propose it. In the report:

- Identify the simplifications made: e.g. elements; shape; materials; loads
- Change the mesh size in the model and discuss how the results change in terms of displacements and stresses. Show comparison of the results.
- Change the material and discuss the impact of this modification to the deflections and stresses. Show comparison of the results.
- Discuss the lessons learned from the assignment.
- **Bonus, 25%**: introduce a large-opening to the model and discuss how the results change in terms of displacements and stresses.

Assignment 2. Ply and large deflections for beams and plates
Given: 11.09.2023
Due: 18.09.2023 09:00

The idea of the assignment is to demonstrate how material model of a laminate will affect the response of the plate in terms of displacements, strains, and stresses.

You need to create a lamina with commercial Finite Element package and expose it to in-plane uniform strain or stress, while computing the other and do the averaging of the resulting distribution (e.g. constant strain, averaging of varying stress). Analyze the responses in terms of displacements and stresses and vary the direction of load with respect to principal direction to see the differences in load-carrying mechanism. In the report:

- Compare the average strain and stress and their ratio (stiffness or compliance), when exposed to 1) uniform strain and 2) uniform stress.
- Show how the load direction affects the results.
- Discuss the lessons learned from the assignment.
- **Bonus, 25%**: non geometrically non-linear analysis for the stiffened panel in week 1. How do the results change due to the von Karman strains?

Assignment 3. Laminates and different structural theories
Given: 18.09.2023
Due: 25.09.2023 09:00

The idea of the assignment is to demonstrate how laminates behave under bending loads.

Make a laminate from several plies and report the stacking sequence and the layer stiffness matrices and thicknesses. Expose the laminate to bending loads with simply supported and pinned boundary conditions. Discuss the effect of boundary conditions to displacements and stress resultants. Change the structural theory from CLT to FSDT and discuss the differences in solutions. In the report:

- Discuss the observations you see from different structural models and reasons for similarities and differences.
- Discuss the lessons learned from the assignment.
- **Bonus, 25%**: change the material in the stiffened panel to laminate. How do the results change in terms of displacements and stresses? Why?

Assignment 4. Offset beams and periodic plates
Given: 25.09.2023
Due: 02.10.2023 09:00

The idea of the assignment is to study the relation between accuracy and computational costs between different models and the sensitivity of the implementation of load and boundary conditions to the responses (displacements and stresses).

In the assignment the stiffened panel from Assignment 1 should be analyzed using both offset beams attached to a plate and by modelling the entire assembly as orthotropic plate. You should consider:
Case 1: plate and stiffeners are modelled with shell elements (Assignment 1)

- Case 2: plate is modelled with shell elements and stiffeners with offset beams
- Case 3: the whole assembly is modelled with orthotropic shell elements

Note! With proper modelling all 3 cases should give almost the same result in terms of displacements and stresses. In the report you need to:

- Discuss the observations you see from different models and reasons for similarities and differences in terms of stresses and displacements.
- Discuss the lessons learned from the assignment. How does the kinematical assumptions made affect the results? Which model is stiffest and why?
- **Bonus, 25%**: change the offset of the beams and discuss how rapidly the results change.

Assignment 5. Fatigue and vibration
Given: 02.10.2023
Due: 09.10.2023 09:00

The idea of the assignment is to demonstrate how fatigue assessment affect the FE-modeling of thin-walled structures.

You need to create a direct mesh refinement to stiffened panel (from Assignment 1) and compute the structural stress at some critical location with the t/2 and 3t/2 extrapolation rule. Run the 3 models from Assignment 4 for vibrations (5 lowest eigen frequencies and modes). In the report you need to:

- Discuss how did you select the mesh size and location for the fatigue assessment.
- Discuss the observations you see from different models and reasons for similarities and differences in vibrations. Focus on kinematical assumptions in the 3 models.
- Discuss the lessons learned from the assignment.
- **Bonus, 25%**: consider an intersection between the stiffener web and the plate and perform extrapolation to the hot spot based on structural stress approach from different from both plate and the stiffener web. How does the extrapolated stress change? Why does it change?

Assignment 6. Buckling, Ultimate and Accidental Strength

Given: 09.10.2023

Due: 16.10.2023 09:00

The idea of the assignment is to show how buckling limit state assessment is affected by the discretization employed in the modelling.

You need to run all 3 FE-models from round 4 for buckling analysis (bifurcation buckling) and discuss how much and why do the results change. As a second task identify the amount of elastic and plastic energy per volume of the material(s) you used in Assignment 1. In the report you need to:

- Discuss on the modelling of the plates and stiffeners and the influence of the simplifications to the buckling strength.
- Discuss the lessons learned from the assignment.
- **Bonus, 25%.** Explain the initial conditions, assumptions, analysis type and control parameters you would use to analyze an accidental limit state of the stiffened panel under spherical impactor. As an alternative explain how you would carry out a ultimate strength analysis under in-plane compression.

Week 1 Group Work - Load and Modelling

Week 2 Group Work - Lamina and large deflections

Week 3 Group Work - Laminates and different structural theories

Week 4 Group Work - Offset beams and periodic plates

Week 5 Group Work - Fatigue and vibration

Week 6 Group Work - Ultimate and Accidental Strength

Individual Assignment - Learning Diary