Aalto University
School of Engineering

COE-C2004 - Materials Science and Engineering

2021-2022 Autumn II

Assignment 3, 15.11.2021

General rules:

1. Learning Group work is encouraged for this course. You could form a group with max one additional peer to review the lecture/exercise content and discuss the tasks in the assignment. After discussion, please finish your assignment independently and submit your individual report. Please note the duplicate report is not accepted!
2. If you have a learning group, please indicate who your group member is in the submitted report. In addition, clearly state the individual contributions of each group member.
3. When required, always show the step-by-step derivation or calculation processes, without which hinting the number does not qualify for grades.
4. When required, always give a brief and concise explanation or description, without which hinting the right choice or answer does not qualify for grades.
5. Citation is necessary if you are using any figures/data that are not generated by yourself.
6. Handwriting/plotting is acceptable, just make sure that your handwriting/final photo in the system is clear enough, otherwise it may affect the grading for details/calculation process.
7. Only PDF type file is accepted for submission, please summarize all your answers/solutions in one PDF file for every assignment. It is appreciated to sort the PDF pages in the TaskNr order, which is helpful to speed up the evaluation process. Please name your assignment files with the assignment number and your first name and surname, and link them with short underlines: 'ANr_Firstname_Surname.pdf', e.g. for the first Assignment 'A1_Wenqi_Liu.pdf'.
8. Assignment 3 will take 7 points in the final grade system.

Due date: 18:00, 21.11.2021.

Contact: MyCourses 'General discussion' channel

Q&A: every Tuesday at 16:30-18:00 (via Zoom: https://aalto.zoom.us/j/62428835336).

Prof. Dr.-Ing. Junhe Lian junhe.lian@aalto.fi Tel.: +358 50 477 0765
Adv. Manufacturing and Materials | Department of Mechanical Engineering | School of Engineering | Aalto University
Mail address: P.O. Box 14200, FI-00076 Aalto, Finland; Visiting address: Puumiehenkuja 3, 02150 Espoo, Finland

Task 1. Fracture mechanics (10 points, Lecture5)

1.1 The fracture strength of glass may be increased by etching away a thin surface layer. It is believed that the etching may alter the surface crack geometry (i.e. reduce the crack length and increase tip radius). Calculate the ratio of the etched and original crack tip radii if the fracture strength is increased by a factor of 7.6 when 37% of the crack length is removed. (Please give the detailed calculation process.)

1.2 A structural component in the shape of a flat plate 17 mm thick is to be fabricated from a metal alloy for which the yield strength and plane strain fracture toughness values are 536 MPa and 25.0 MPa$\sqrt{m}$, respectively. For this particular geometry, the value of Y is 1.3. Assuming a design stress of 0.4 times the yield strength, calculate the critical length of a surface flaw. (Please give the detailed calculation process.)

Task 2. Charpy test (20 points, Lecture5&6)

2.1 Please use the test results given in Table 1 to fit the transition curves for steel A. Give your fitting function and fitted parameters, show the fitting figure. (Hint: Use a proper equation e.g. the Boltzmann function to fit the data.)

Table 1 Charpy test results of steel A.

T, °C	-196	-140	-120	-120	-120	-100	-100	-100	-78	-78	-78	-40	-40	-40	25	100
A_V, J	10	12	33	19	18	26	41	30	86	105	129	210	243	220	245	246

2.2 Based on your curve fitting in Task 2.1, give the following characteristic values of a Charpy test:
(a) What is the temperature (in °C) with an impact energy of 27 J?
(b) What is the upper shelf toughness A_{Vmax} (in J)?
(c) What is the transition temperature $T_{AVmax/2}$ (in °C)?

2.3 Please add the schematic transition curve of an FCC material on the fitted curve in Task 2.1, and explain the failure mechanisms of BCC and FCC materials in Charpy tests at different temperatures.

2.4 The force–deflection curves of two Charpy impact tests are shown in Figure 1. Both of the tests were performed at 30°C. The areas under these two curves are the same, i.e. I=II. Which steel shall have a lower transition temperature? Please explain the reason.

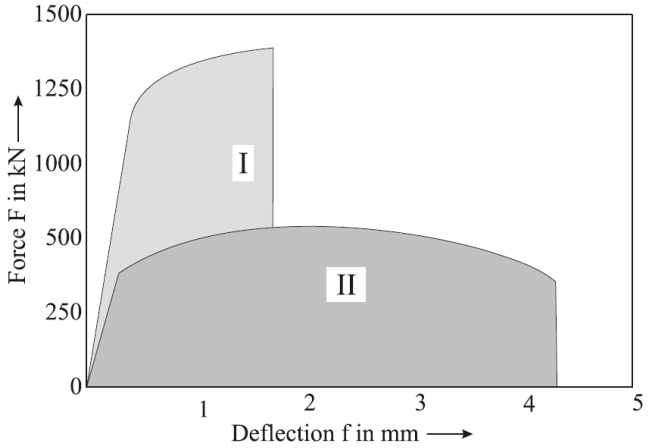

Figure 1 Force–deflection curves for the Charpy test. [1]

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Task 3. Failure behavior (30 points, Lecture5&6)

Choose three of the failure types of metals from the list, and give a description of each:

- Creep,
- Fatigue,
- Corrosion,
- Cleavage fracture,
- Ductile fracture,
- Abrasion.

The description shall include the following aspects:

(1) a brief definition of this term,
(2) an example,
(3) the conditions/situation this failure might happen,
(4) affecting factors,
(5) how to improve the resistance to this kind of failure.

Task 4. Simulation (25 points, Exercise3)

Build up the 2D CAE model according to the specimen geometry drawing in Figure 2. Run a plastic deformation simulation until 10% global engineering strain using the flow curve given in A3T4data.txt. Define the boundary conditions. Give the resulting von Mises stress and strain distribution patterns for the whole sample, including the legends. Extract and plot the reflection force–displacement curve. (Hints: Use the ¼ symmetry model. Use a mesh size as finer as possible with total nodes less than 1000. Show your definition of loading condition for the requested global engineering strain. Except for the final result patterns, you are welcome to give any necessary figures to show your simulation process.)

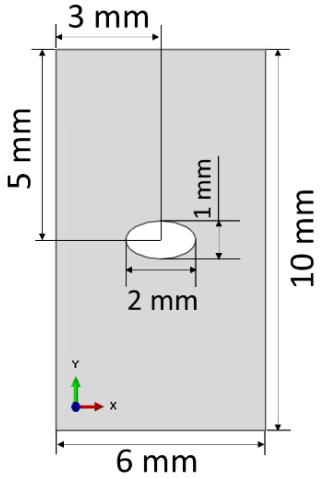

Figure 2 Specimen geometry drawing for Task 4.

Task 5. Self-assessment (15 points)

It is right in the middle of the course. We only have a half to finish the course in about 3 weeks. Please take a moment to reflect on what you have learned during the first half of the course and assess your learning experience. The writing format is flexible and write it in a way as your learning diary.

Reference

[1] W. Bleck, *Materials Science of Steel*, Department of Ferrous Metallurgy, RWTH Aachen University, 2013.

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