Exercise 3

INTRODUCTION TO PROCESSING OF THERMOSET COMPOSITES
Task 1: Hand-lamination Process

a) Estimate the amount of resin required for the fabrication of a glass-fiber plate of dimensions 500 x 600 mm with the hand-lamination process. (assume that 30 % of volume of the resin is wasted during the mixing and the lamination process)

- Glass fiber textile: $A_w = 420 \text{ gsm}$
- Number of Layers: $N = 12$
- Density of glass fiber: $\rho_f = 2.5 \text{ g/cc}$
- Density of the resin: $\rho_r = 1.5 \text{ g/cc}$

b) Give three examples of application of the hand lamination technique in the industry. Which are the major advantages of this process?

c) Describe the typical vacuum bagging layup used in the hand-lamination technique. Which mechanism permits to increase the quality of the laminate?
Task 2: Rheology of Thermoset systems

a) Technical datasheets of resin systems report the gelation time at the processing temperature.
   - What is the meaning of gelation time? How do the properties of the resin evolve after this time period?
   - Consider the steps of the hand-lamination process presented below, when is the resin allowed to gel? (motivate your answer)

   ![Hand-lamination process diagram]

   - Which options are available for the manufacturer to influence the gelation time?
b) The graph presented below describes the evolution of the degree of cure (\(\alpha\)) in time of a resin system at isothermal conditions (80°C). Considering the data of the graph and the following viscosity model, answer to the questions:

\[
\mu = A \cdot e^{\left(\frac{B}{T}\right)} \cdot \left(\frac{\alpha_g}{\alpha_g - \alpha}\right)^{C+D\cdot\alpha} \quad [Pa \cdot s]
\]

Where:

- \(A = 0.04\), \(B = 400\), \(C = 0.4\), \(D = 0.4\), \(\alpha_g = 0.71\)

- The maximal viscosity for the processing of thermoset system with infusion technologies is set at 200 mPa*s. Calculate the processing time of the resin at 80°C.

- What is the viscosity of the resin at 30°C? If the curing reaction takes place very slowly and its influence on the viscosity profile can be neglected. What would be the processing time for the resin at 30°C?

- Draw qualitatively the evolution of the resin viscosity in time at 30°C, 80°C and 120°C. Comment on the graph.
**Task 3: Capillarity and injection velocity**

a) A resin system is flowing slowly through a unidirectional (UD) fiber textile. The capillary action is driving the flow. Draw the steps of the formation of a macro-porosity in these flow conditions.

b) In impregnation processes of fiber textiles a minimal velocity of the flow front exists. Explain why. (consider a constant viscosity fluid)

c) Two unidirectional textile samples are partially immersed in an Oil reservoir (fiber are orientated vertically). The sample A has a fiber volume fraction of 45% and sample B of 55%. In steady-state condition, the fluid in sample A reaches a height of 276 mm. Assume that the fiber radius is the same in both textiles.

- Which is the height of the fluid in sample B in steady-state conditions?

- During the impregnation process, in which sample will the fluid flow faster?