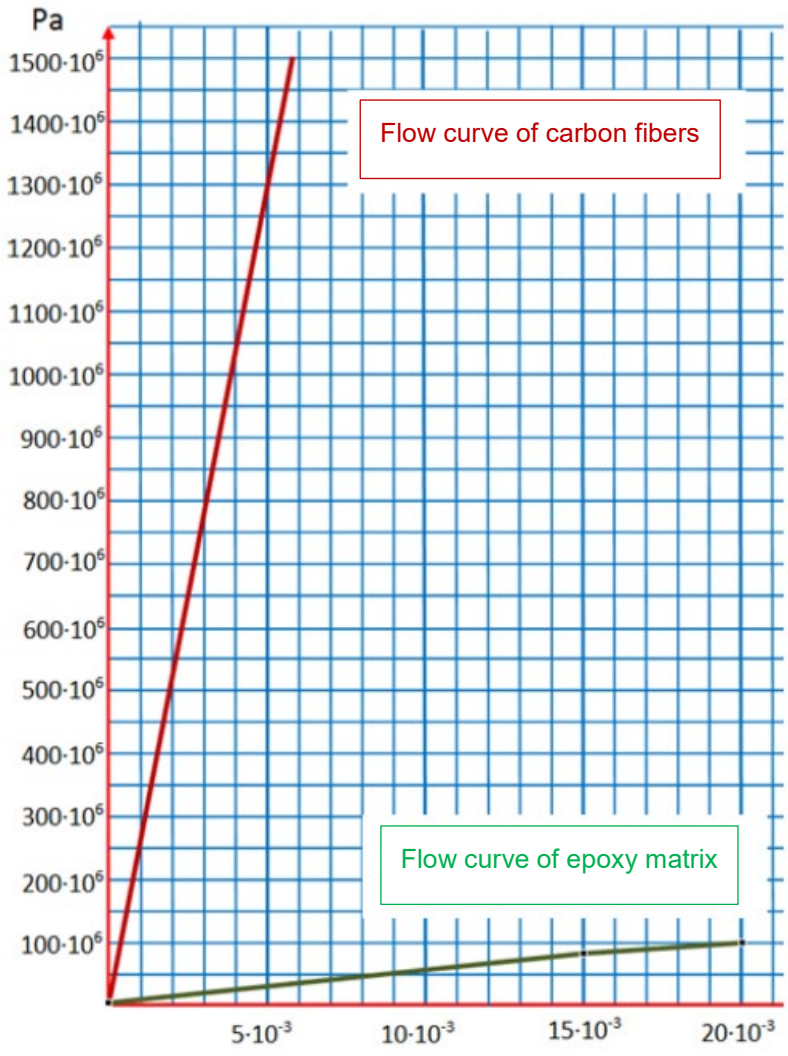
Lesson 13: Composites and materials indices

Exercise 13.1:

A machine part is to be manufactured as a polymer matrix composite with carbon fibers and an epoxy as matrix. The properties of the constituents are as listed:

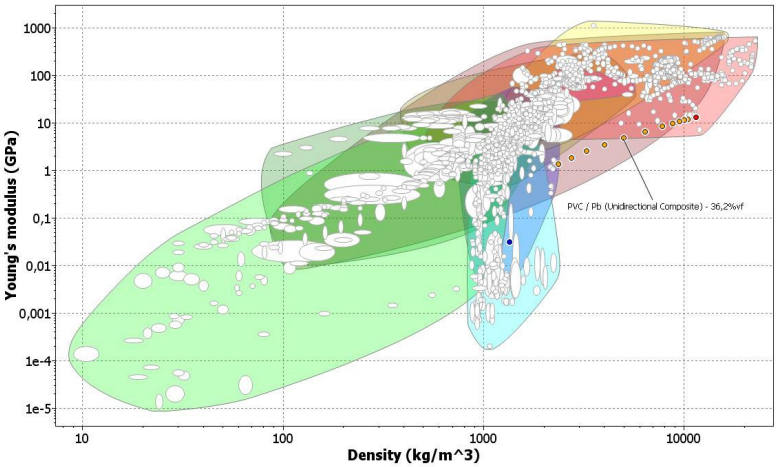
Diameter of carbon fibers	d	20 µm
Tensile strength of carbon fibers	σ_f^*	1500 MPa
Young's modulus of carbon fibers	E_f	260 GPa
Young's modulus of epoxy matrix	E_m	2.4 GPa

The graph shows the stress strain curve of both materials.



1. What will be the Young's modulus of the composite along the fiber direction, if long, continuous carbon fibers with a volume fraction of 30% are parallel aligned?
   $E_c = f_f E_f + f_m E_m = 80$ GPa
2. Read from the graph:
   a. Fracture strength of epoxy σ_m^* = 100 MPa
   b. Stress in matrix, when carbon fibers crack σ'_m = 30 MPa
3. Calculate fracture strength of composite with long, continuous carbon fibers and a volume fraction of 30% for the loading along the parallel aligned fibers.
   $\sigma_c^* = f_f \sigma_f^* + f_m \sigma'_m = 471$ MPa

Exercise 13.2: Composites (Use ANSYS GRANTA EduPack)
Design a polymer matrix composite material with help of ANSYS GRANTA EduPack.
1) Use database level 3 Aerospace.
2) Allow all bulk materials.
3) Create a property map showing the relation between Young's modulus and mass density.
4) Is there a material with density 5000 kg/m^3 and Young's modulus 5 GPa?
5) Use the synthesizer tool (under Tools) for simulating the properties of a fiber composites (unidirectional, continuous fiber composite) made of two materials (e.g. PVC (flexible, Shore A85) as matrix and Lead, commercial purity, chemical as fibers) with different volume fractions of fibers (10%-50%).
6) Can a polymer matrix composite be created with density 5000 kg/m^3 and Young's modulus 5 GPa? Which volume fraction of fibers is required? About 36 wt%



Exercise 13.3: Supporting table
Construction of a supporting table requires that its four legs (idealized as circular rods of given length L) will not deform plastically under a given load. Which is the material of choice, if the weight is desired as low as possible? What is the relevant material parameter/index?

See lecture. For a strength limited design in compression the relevant material index is σ_y/ρ.