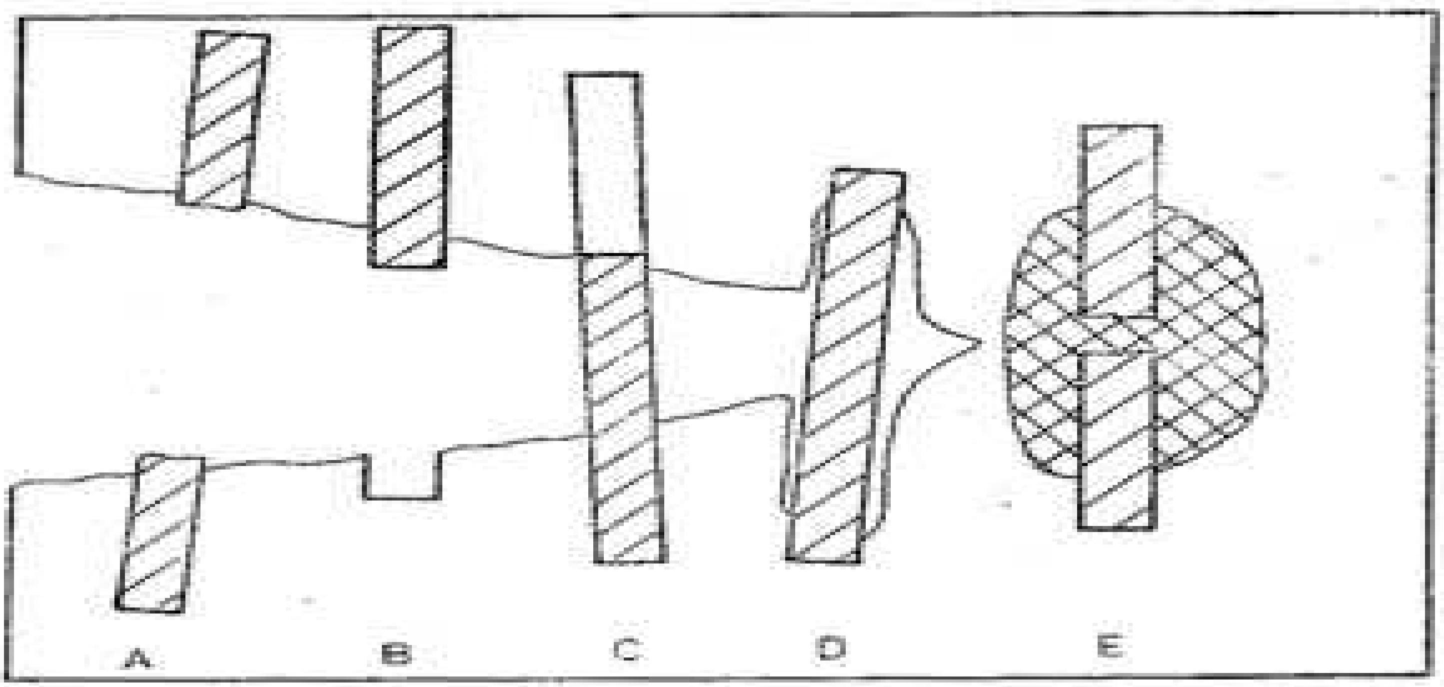
Tensile strength fibre composite



Calculation assumptions

We start from the arrangement Voigt's model

All fibers have the same cross-section

All fibers have the same tensile strength

All the fibers are parallel and stretched

The fibers are uniformly distributed over the cross section

Known tensile strength and strain at fracture matrix and dispersion

Models must be distinguished by the ratio of deformation matrix and dispersion by the fracture of composite

The same ductility of matrix and dispersion

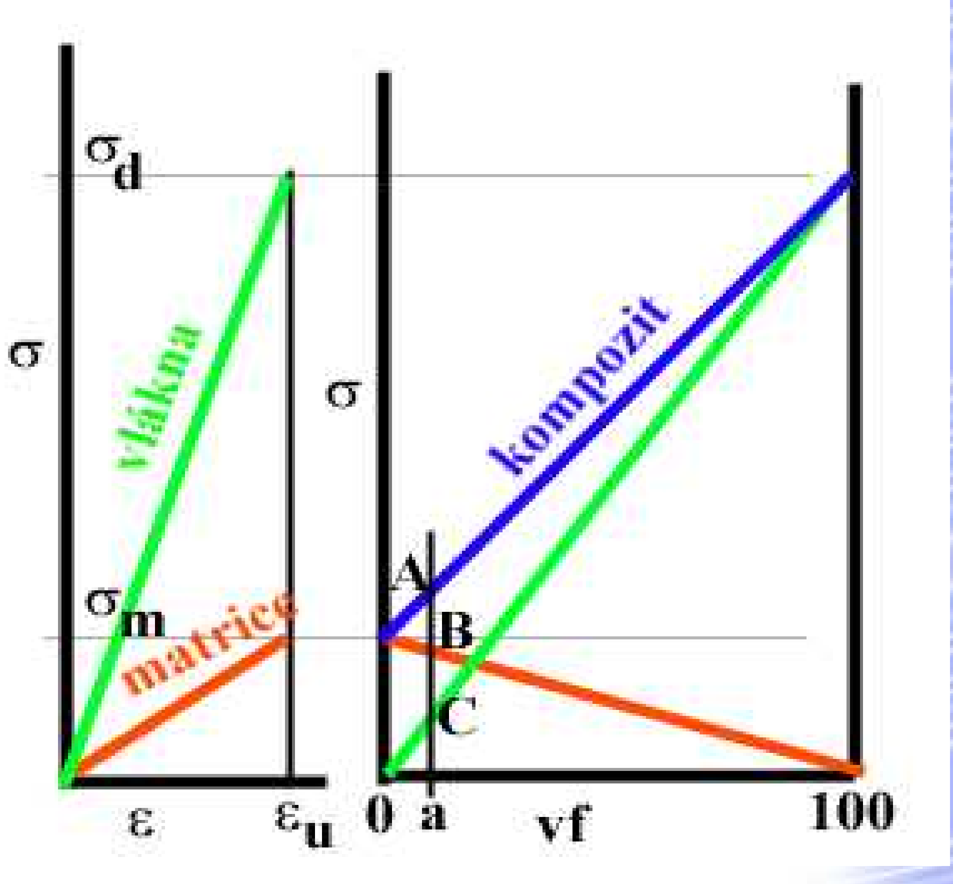
Left – idealized tensile diagrams

ε_u – deformation by break

σ_d resp σ_m – strength of fibers resp matrix

Right – strength of fibers , matrix and composite depending of the amount of fiber.

The amount of fibers a – by that has composite tensile strength A, at the same moment stress of fiber C in and stress of matrix B



Relevant tensile strength

Relatively rare case of composite.

Approximately valid for the combination:

The glass fibers, epoxy matrix

- Tensile strain at fracture for both 5%

Fiber and matrix rupture simultaneously, for tensile strength relationship applies:

$$\mathbf{R_{ku} = R_{du} * v_d + R_{mu} * (1 – v_d)}$$

or :

$$\mathbf{R_{ku} = R_{mu} + v_d * (R_{du} - R_{mu})}$$

Tensile strength of composite always greater then that of matrix

Greater ductility of matrix

Very often – ductility of matrix is greater than of dispersion.

Diagrams left.

First, we achieve the maximum deformation in the fibers - the first thus break fibers.

Instead fibers are now

in the matrix hole - stress drop in the composite.

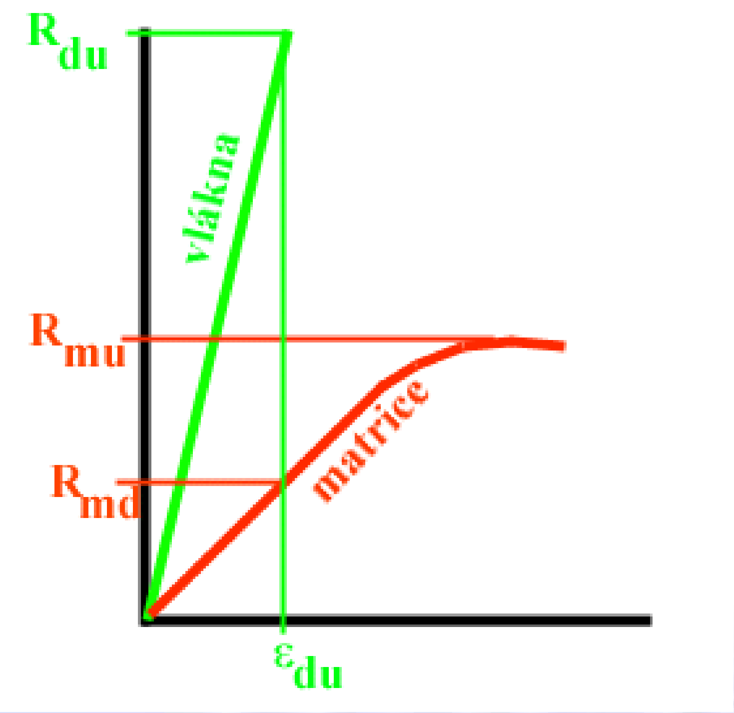
The tension in the matrix increases further to its tensile strength, the matrix breaks

Green … fibers, red … matrix

R_{du}, R_{mu} – tensile strength of fibers, resp matrix

ε_{du} – deformation of fibers by break

R_{md} – stress in matrix by break of fibers



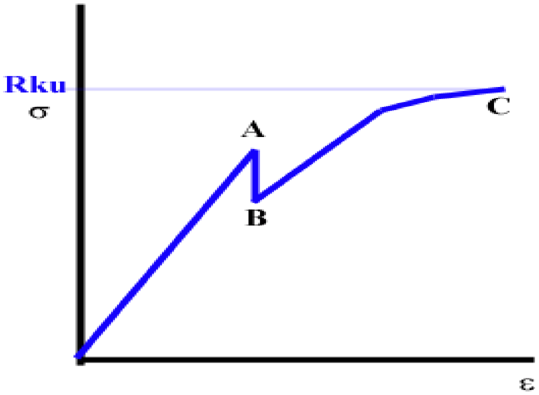
Dependence on the amount of fiber

In point A break fibers.

This reduces the overall stress in the composite to point B, because now the load is only in matrix.

Further stress increases until point C is reached the tensile strength of residual matrix (with voids).

For a small number of fibers (under v_{fkrit} - can be calculated) determines the strength of the composite matrix with holes on broken fibers.



$$R_{ku} = R_{mu} * (1 - v_f)$$

Tensile strength of composite is less then tensile strength of matrix

Tensile strength

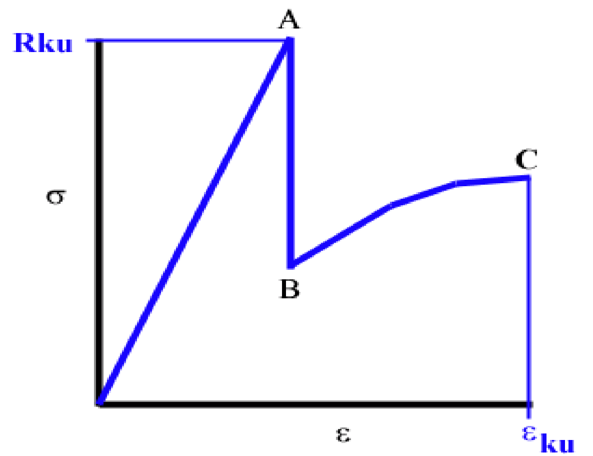
In point A break fibers.

This reduces the overall stress in the composite from point A to point B, because now the tension is only in matrix (with threaded holes)

Further stess increases until point C is reached where the matrix fracture occurs.

Tensile strength of the composite is determined by the fiber at the point A

Fracture occurs but in point C.



We need to distinguish ultimate tensile strength (point A) and fracture of composite (point C)!

Tensile strength

Tensile strength of the composite is determined by the break of fibers.

Tensile strength is not the same as stress by break of composite - composite can still far beyond the tensile strength to remain intact, but with reduced stiffness and stress.

For the tensile strength, the basic relationship

$$R_{ku} = R_{du} * v_d + R_{md} * (1 - v_d)$$

Tensile strength of composite is greater, the greater the tensile strength of the fibers and they are more.

Since the amount of fiber v_{min} is tensile strength of composite gerater than tensile strength of matrix itself. Smaller amounts of fiber does not make sense

Critical volume of fibers

By v_{min} must bouth relations for tensile strengt give the same value

$$R_{mu} * (1 – v_d) = R_{du} * v_d + R_{md} * (1 – v_d)$$

From that

$$\mathbf{v_{min} = (R_{mu} – R_{md}) / (R_{du} + R_{mu} – R_{md})}$$

It is obvious that it is most important the ratio of the strength of fibers and matrix, the greater is, the smaller v_{min}.

If $R_{du} >> R_{mu}$, approximately

$$\mathbf{v_{min} = (R_{mu} – R_{md}) / R_{du}}$$

Value R_{md}

Constant R_{md}, stress in matrix by break of fibers, is very important. As can we see, determines value of v_{min} and tensile strength of composite. Therefore, it must be at least estimated.

If we know tensile strain diagram of matrix, it is possible to deduct the value of R_{md} from that diagram for deformation ε_{du}

If the matrix material is ductile enough and has a substantially greater elongation than the fibers, can be used as an estimate for the R_{md} yield strength of the matrix

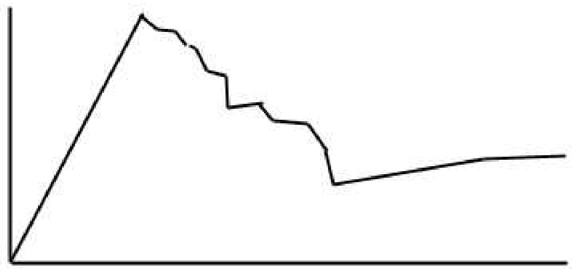
Examples v_{min} from yield strength - approximately

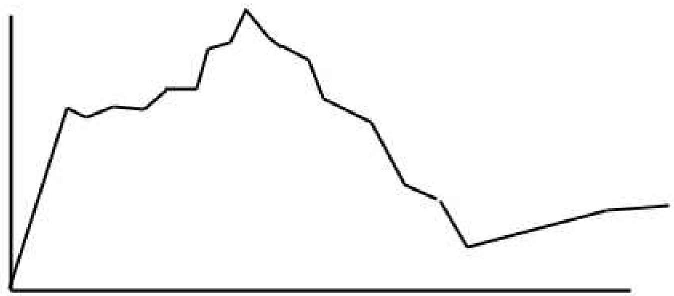
material	R_{pt} MPa	R_{kt} MPa	ε_u %
Epoxy	60	20	5
steell	320	200	10
C-fiber	2000	---	0,4

For C fiber in epoxy :
v_{min} = (60-20)/(60+2000-20) =1,96 %

For C fiber in steel :
v_{min} =(320-200)/(320+2000-200) =5,7 %

Influence of dispersion properties of fibers



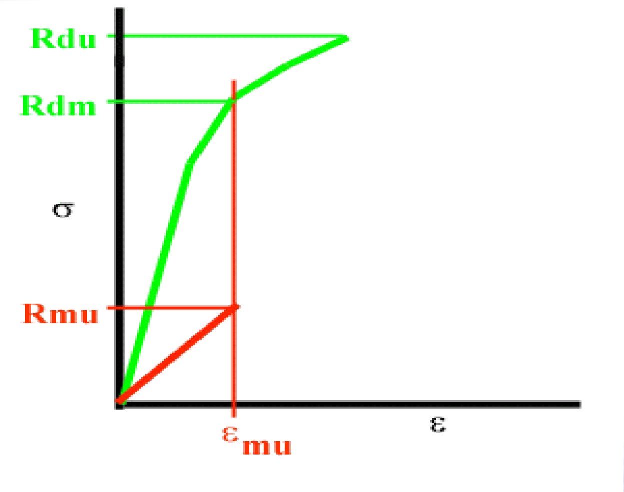


The fibers typically have large scattering properties.

Break not by one stressge in one, but breake gradually, so that the real work diagram looks as shown on the top left, and with a large scattering properties as shown on the top right.

Greater ductility of fibers

Green … fibers,
red … matrix
R_{du}, R_{mu}
– tensile strength
of fibers, matrix
ε_{mu} – deformation of
matrix by break
R_{dm} – stress in fibers by
break of matrix



Often – ductility of matrix is less than of dispersion.

Diagrams right.

First, we achieve the maximum deformation in the matrix - the first thus break matrix.

Fibers begin to stretch

even in places where there is matrix corrupted.

The matrix may break

on fibers repeatedly

Tension in the fibers grows up

their tensile strength, when the fibers break.

Breaking of composite

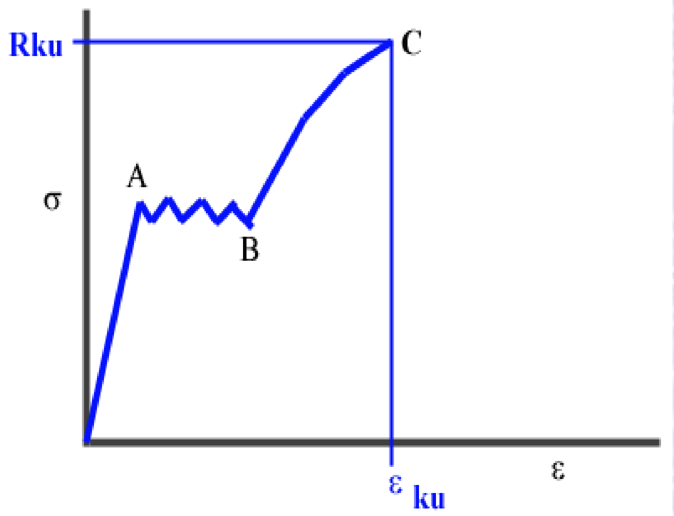
At point A, the matrix breaks.

The fibers stretch and strain in the composite decreases to point B.

A further growth of the stess again break the matrix

This process continues until the entire matrix cracks into slices strung on fibers.

The tension in the fibers in the composite is growing up at point C is broken fibers.



Tensile strength

Tensile strength is determined only by the volume concetration and tensile strength of fibers

The properties of the matrix matter only an apparent yield stress of composite.

For the yield strength we have relation

$$R_{ku} = R_{du} * v_d$$

The matrix is broken down into a series of plates joined with fibers.