Adhesive force in composite

Contents of lecture

- 1. Adhesive force on boundary of materials
- 2. Wettability
- 3. Methods of adhesion measurement

Bond on boundary between phases

Between two phases in composite are interphase boundaries.

Possible forces on boundary :

Mechanical coupling

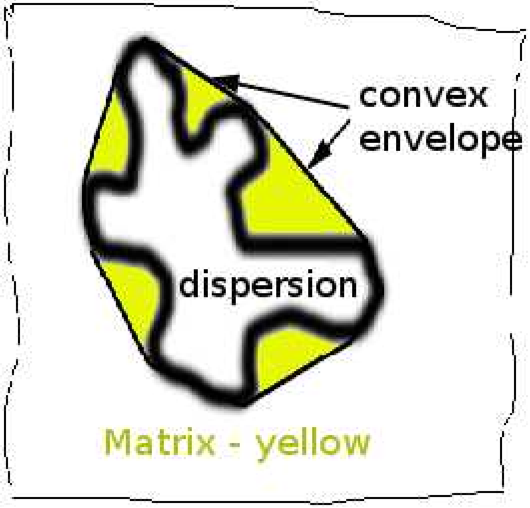
Physical bond (Van der Vaals)

Chemical bond

Mechanical coupling

Particles of phases are wedged –depend on curvature of boundary

Yellow parts of matrix hold the particle on place.



Convex envelope of particle
– as rubber fibre around particle

Characterisation of mechanical coupling
- surface of particle divided by surface of convex envelope.
Particle or fibre must not be very smooth

Physical bond

- Have effect on distance 0,3 up to 0,5 nm

Theoretical magnitude 0,7 up to 7 GPa

Is closely related to wetting of bouth materials

Is expressed by surface tension or surface energy.

If is possible diffusion on boundary, is made stronger bonded diffusion interlayer
– bor in steel

But by diffusion interlayer is risk, that little particles are dissolved.

Chemical bond

If matrix and dispersion can together chemical react.

Is formed interlayer of chemical compound with chemical bond.

Can be, that all original dispersion is in compound – thereafter is dispersion that compound.

Chemical bond have effect on distance 0,1 up to 0,3 nm

Theoretical magnitude is 7 up to 70 GPa

Cause of poor cohesiveness

As we can see, bond forces on boundaries are great enough, as far as they arent disturbed :

- Surfaces of matrix and dispersion are not enough close, or only part of surfaces

- Surfaces arent clean – grease, fat, oxides

- Great tension on boundaries – diverse thermal expansivity and phase transformations

<u>Main part is wetting on boundary</u>

Wettability – basic idea

Surface tension – force necessary for enlargement of circumference of boundary by unit .... γ [N/m] - vector

Surface energy – energy necessary for enlargement of area of boundary by unit .... E [J/m²] - scalar

Bouth quantities are numeric equal (but not type)

Main equilibrium for wetting of surface : G – surrounding gas, S – solid, L – wetting fluid

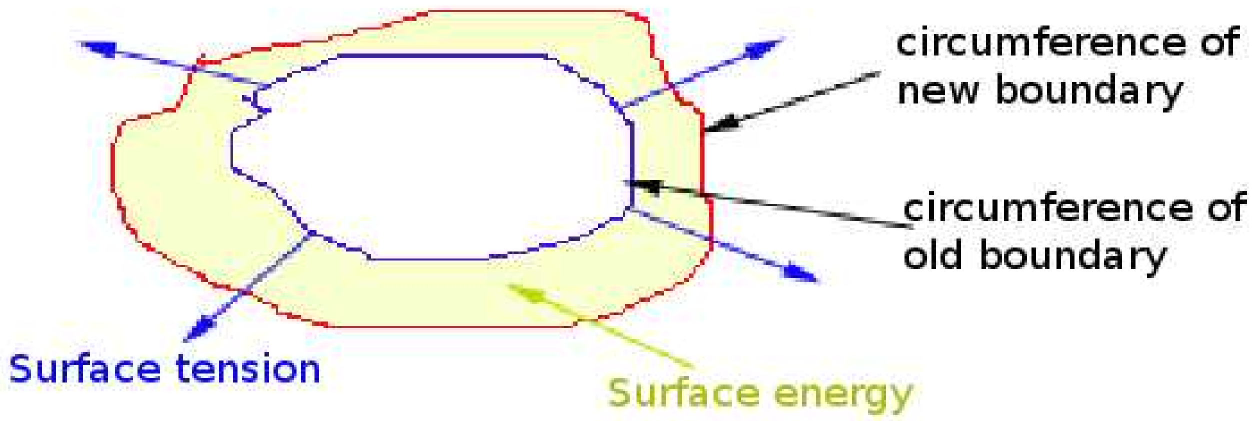


Chart of wetting at composite

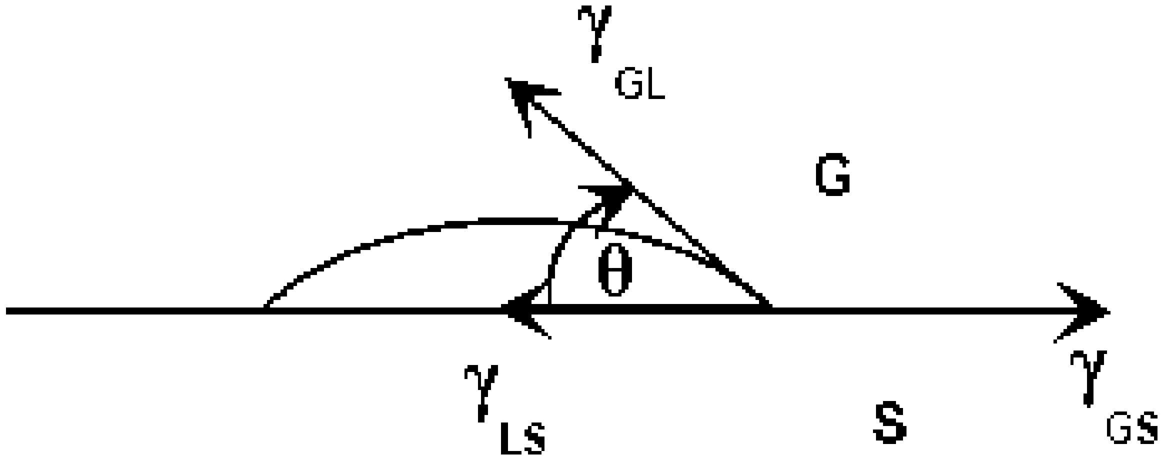
S surface of dispersion

L surface of liquid matrix

G sorrounding gas

Force equilibrium :

$$\gamma_{GS} = \gamma_{LS} + \gamma_{GL} * \cos\theta$$



Good wettability of boundary

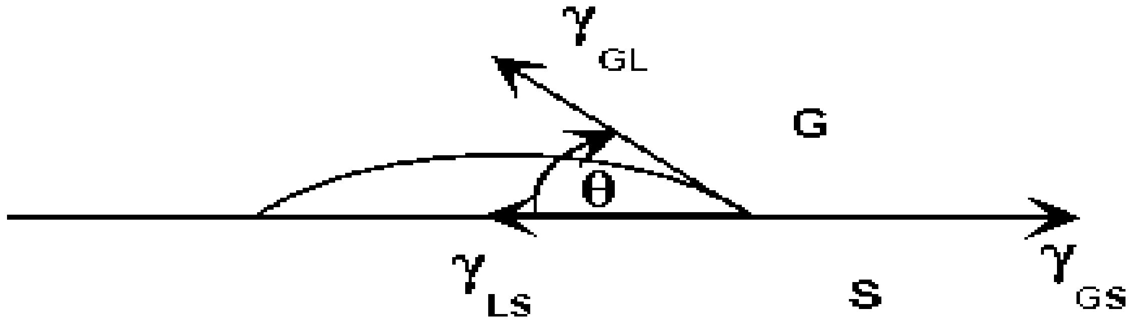
Boundary is good wetted by $\gamma_{GS} > \gamma_{LS}$, then by growth of boundary LS nd decrease of surface GS surface energy go down.

That is by $\theta < \pi/2$

Liquid create form according to figure

$\theta = 0$ ..... ideal wettability, continous layer of liquid on solid

$\theta = \pi/2$ .... limit case, half - sphere



Poor wettability of boundary

Boundary is not wetted by $\gamma_{GS} < \gamma_{LS}$, so $\theta > \pi/2$

Liquid create form according to figure, there are single drops

$\theta = \pi$ ….. none wettability, drops on surface, contact only in one point

$\theta = \pi/2$ …. limit case, half - sphere

Influence of surface roughness

Factor of roughness D = real surface / ideal surface without roughness, always D > 1

Valid is $\cos \phi_{rough} = D * \cos \phi_{ideal}$

Good wettability .... $\cos \phi > 0$, descending function $\phi_{drsne} < \phi_{idealni}$
– roughness improves of adhesion

Poor wettability .... $\cos \phi < 0$, ascending function, $\phi_{drsne} > \phi_{idealni}$
– roughness deteriorates of adhesion

Methods of adhesive stress measurement

There are tangencial and normal adhesive stress, both are each other independent.

Opportunity of calculation from wettability – very difficult, many of assumtions and simplifications.

Measurement on massive specimens

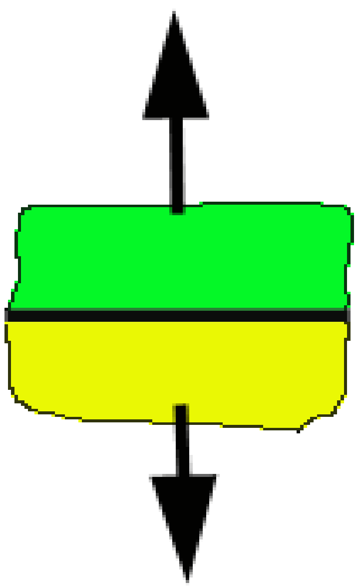
Measurement adhesion of layer on substrate

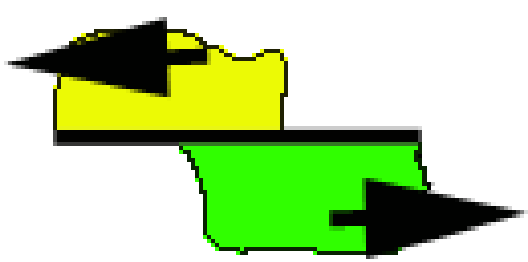
Technological methods of measurement

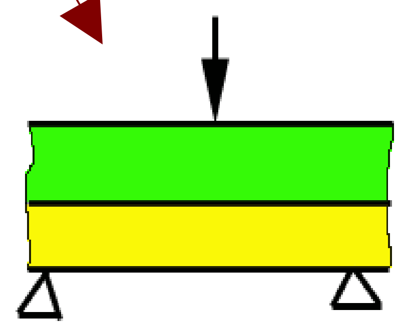
Measurement directly on composites

Masive specimens

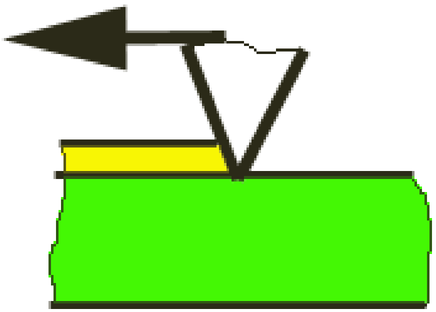
- Draw test – normal adhesive stress
- Slide test – tangential adhesive stress
- Bending test – tangential adhesive stress – delamination boundary must be in neutral plain. Bending of thick short specimen



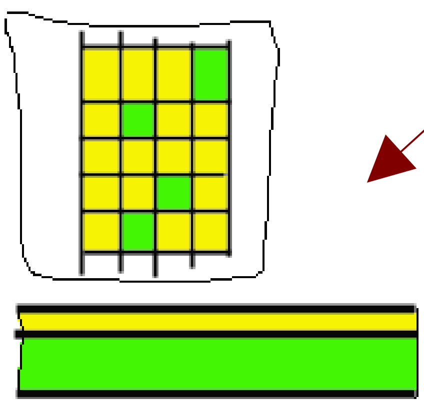




Layer on substrate



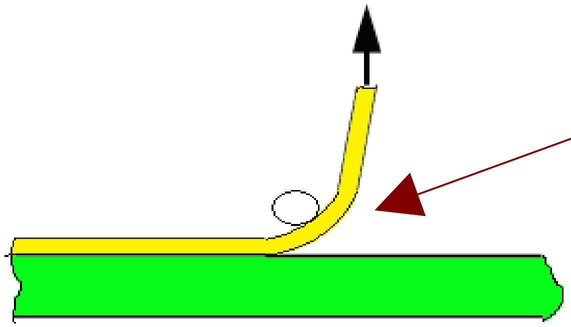
Scratch test – tearing off layers with Rockwell indentor, compare value is force for teareng off layers

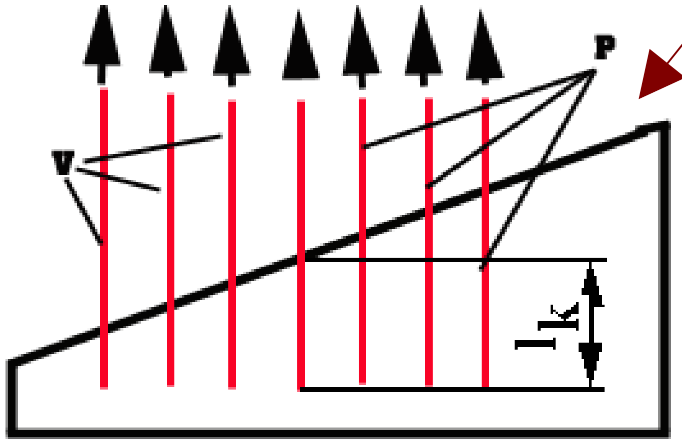


Gitter (scratch) test – twice 10 scratches perpendikular on oneself, compare value is percent of squares fallen out after tearing off with adhesive tape

Only comparative tests

Technological methods





Tearing test – very often by plastic tapes

Also suitable by thick layers of flexible lacquer

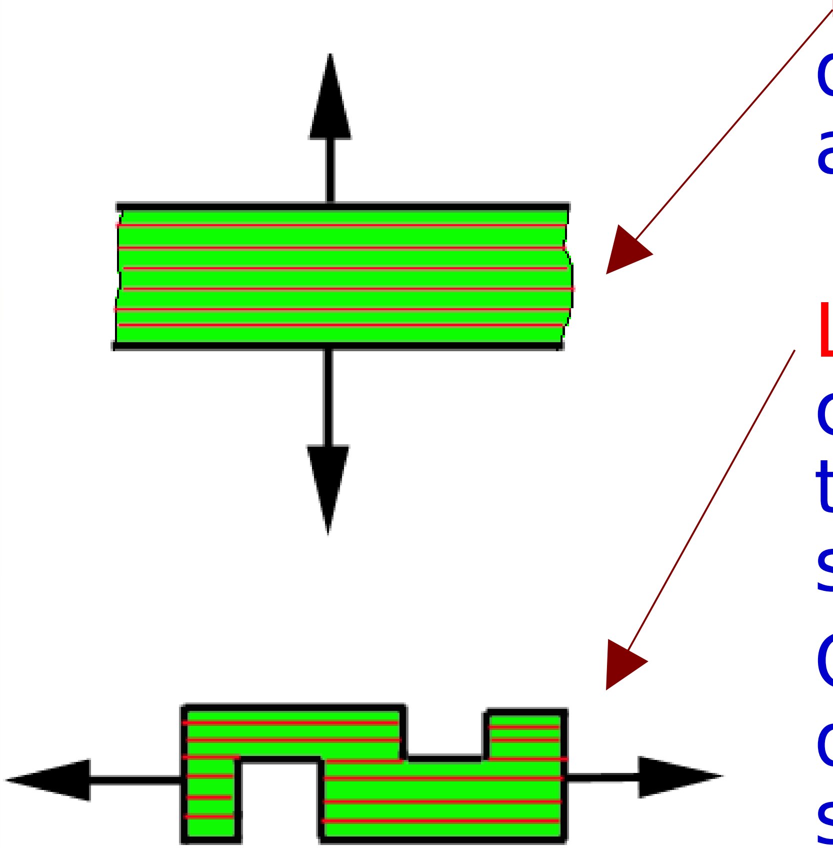
Pull out test – one of main tests of fibre composites

V – pulling out fibres

P – breaking fibres

Between in critical length of fibre l_k

Directly on composites

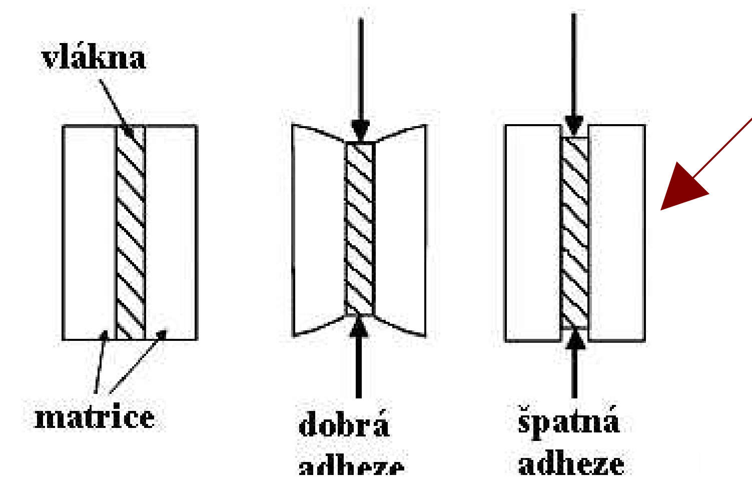


Transverse test – determines normal adhesive stress

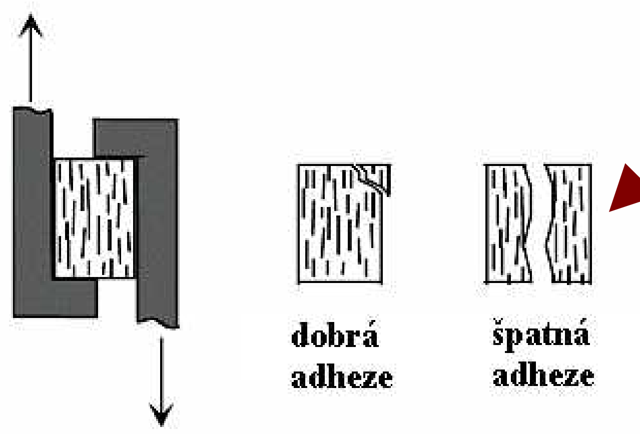
Longitunal test with cut-out – determines tangential adhesive stress

Complex straining – difficult canculation of stresss, therefore only approximate

Appraisal of good adhesion



Observation of fibre ends by longitudinal draught of composite



Observation of fracture surface by cutting of composite

Microstructure of fracture surface and adhesion