New Scientific Results

Based on my experimental and modelling results, I formulated the theses below [1-13]:

1. I drew the following conclusions from the geometrical and strength examinations of fiber heads in the set of basalt fibers produced with Junkers technology:

   a. I proved with light microscopic images that the fiber heads are of two characteristic shapes, and can be approximated with simple geometrical forms: ellipsoid and truncated cone + semi-ellipsoid.

   I revealed that their ratio in the fiber set is 2:3 in average. I proved that their volume distribution is of exponential characteristic and can be described with the following general formula:

   $$y = A_1 e^{-\frac{V_{szf}}{t_1}}$$

   If χ^2=33.03, which is suitable at 95% confidence level, where V_{szf} is the fiber head volume, and the values of variables are: A_1=166.25, t_1=15.63.

   b. I introduced the term 'break-off strength' for fiber heads; it is the ratio of the tensile force between the fiber and the fiber head and the fiber cross section. I found that the 'break-off strength' can be approximated with a function of third order as a function of the ratio of characteristic fiber head and fiber diameter:

   $$\sigma_{szf} = a_x(D_1/d)^3 + b_x(D_1/d)^2 + c_x(D_1/d) + d_x,$$

   with a correlation coefficient of R = 0.968, where D_1 is the characteristic fiber head diameter, d is fiber diameter, σ_{szf} is the 'break-off strength' of the fiber head, and the values of the variables are: a_x=0.04, b_x=-2.83, c_x=68.70, d_x=-7.94.

   c. I verified that the following general relation exists between the half cone angle (β) introduced for the truncated cone + semi-ellipsoid shape and the characteristic fiber head diameter (D_1):

   $$\beta = \beta_0 + A_1 e^{-\frac{D_1}{t_1}}$$

   with a correlation coefficient of R=0.972, and the values of the variables are: β_0=32.35, A_1=-45.21, t_1=129.67.

2. I extended the statistical fiber mat model that describes the strength reducing impact of fiber heads formed during Junkers fiber production. I substituted the fiber heads with equivalent spheres, and I created fiber head spheres of centrally larger radius around these, and handled them as 100% flaw places. I proved that the ratio of the part of the

environment of fiber head sphere radius created around the breakage cross section that intersects the specimen and the total volume of fiber heads intersecting it is (ϕ_{BV}):

$$\phi_{BV} = 1 - \frac{4\pi K}{3} E\left(\rho^3\right),$$

where K is the center density of fiber heads and ρ is the fiber head radius.

With the help of this relation, the strength reducing impact can be estimated.

I verified the size of fiber head spheres, involving the impact of excess stress in the matrix, and their influence on tensile strength with tensile testing of single fiber heads embedded in the matrix, and I found the following relations:

a. The impact of fiber heads on strength can be described with an exponential relation as a function of distance from the theoretical breakage cross section. The general equation is:

$$\sigma_c = \sigma_{c0} + A_1(1 - e^{\frac{t}{t_1}})$$

with a correlation coefficient of R=0.990, where σ_c is the tensile strength of PP with fiber heads, t is the distance of the fiber heads from the theoretical breakage cross section, and the values of the variables are: σ_{c0}=26.60, A_1=0.934, t_1=0.280.

b. I proved that the relation between the fiber head volume and tensile strength can be described with the following relation:

$$\sigma_c = a_x V_{szf} + b_x$$

with a correlation coefficient of R=0.986, where V_{szf} is the fiber head volume, and the values of variables are: a_x=-0.116 and b_x=27.535.

3. I drew the following conclusions from the help of examinations carried out on basalt fiber reinforced polymer composites produced with melt mixing and hot press:

a. I examined the fiber length in the reinforcing fibers and basalt fiber content in composites. I found that an exponential relation of second order exists between the average value of fiber length and fiber content, and it can be described by the following general formula:

$$\bar{l}_{szál} = \bar{l}_{szál0} + A_1^{\frac{-Bt}{t_1}} + A_2^{\frac{-Bt}{t_2}}$$

with a correlation coefficient of R=0.986, where $\bar{l}_{szál}$ is the average basalt fiber length, Bt is basalt fiber content, and the values of variables are: $\bar{l}_{szál0}$=0.188, A_1=0.532, t_1=0.018, A_2=0.427, t_2=8.043.

b. I applied the fiber bundle cell model of Vas for the tensile tests of the same materials, and this way I determined the lower and upper limit of the critical fiber length of composite reinforcing materials knowing the initial point of the ‘composite failure line’. The model was extended to composites of different fiber length, and this way I determined an ‘effective composite failure’ line.

4. I modified the Kelly-Tyson equation according to the critical fiber length reducing impact of basalt fiber heads. I determined ϕ, which is the ratio fibers with fiber heads and all fibers, knowing the size distribution, shape and volume fraction of fiber heads. Based on this I proved that the Kelly-Tyson formula can be modified for the whole set of fibers in the following way:

$$\frac{l_c}{d} = \left(1 - \phi \frac{\sigma_{szálfej}}{2\sigma_f}\right)\frac{\sigma_f}{2\tau}$$

where σ_f is the fiber tensile strength, $\sigma_{szálfej}$ is the ratio of the tensile force between the fiber and the fiber head and the fiber diameter, l_c is the critical fiber length, d is fiber diameter, and τ is the interfacial shear strength.