Shearing of the fiber-matrix composite material and elastic properties of unidirectional ply

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Abstract: The present work aims to describe the behavior of the interface using the method of load transfer between fiber and matrix in a composite material. Our contribution was first to simulate the mechanical behavior of a composite, for a given radius of the fiber was able to automate the result for different rays thus different proportions of the reinforcement, the simulation was done with software as covered Comsol multiphysics With Matlab, taking into account the boundary conditions.
The thermomechanical behavior is deduced by a mathematical model that describes the variation of the shear stress along the interface; It is found that the shearing of the interface increases with the crosslinking temperature. This increase is partly due to the difference in expansion coefficient between fiber and matrix. The composite studied is the T300/914; Carbon-Epoxy.

Keywords:
interface, fiber, matrix, thermal expansion, damage, shear.

1. Introduction

Composite materials with fiber reinforcements are used in structural applications where mechanical properties are essential. The charge transfer fiber-matrix is largely conditioned by the mechanical response of the interface. The interface is the locus of concentration of defects that Bikerman called weak boundary layers [1]. Thanks to a finite element analysis, Broutman and Agarwal [2] have confirmed the role of the interface, this study has been illustrated by the work of Théocaris [3], and the model of Adams [7].
For a single fiber surrounded by matrix, many analytical solutions have been proposed to evaluate the shear stress along a fiber, the Cox model [8] in the elastic case and the model of Kelly [6] and [9] in the case plastic.
We also see in the work of Piggot [5] and [10] On the other hand, the technique is well explained by Favre [11].
We became interested in two materials with different characteristics (the Peek / APC2 and T300 / 914); Our contribution has been to follow the evolution of the thermo mechanical behavior by establishing a new mathematical model that describes the variation of the shear stress along the interface depending on the thermo mechanical properties and difference expansion coefficients of the fiber and the matrix the other side was homogenized by a finite element code Comsol multiphysics-to measure the mechanical properties of composite and was automated simulation with Matlab software as covered to show the influence of fiber-matrix volume fractions.

2. Modelisation

Consider a representative volume element RVE consisting of a fiber radius and length surrounded by a matrix cylinder radius. The fiber gives a volume fraction with
Solving approach by the constraint method is to:
• establish the equilibrium equations.
• Propose a solution constrained by the law of thermo-linear elasticity.
• Check the boundary conditions in effort.

2.1 Getting equations:

The load transfer between fiber and matrix operates in the vicinity of a discontinuity in the fiber or the matrix. This results in a stress gradient in the fiber is balanced by an interfacial shear

τ_i:

$$\frac{d\sigma_f}{dx} = -\frac{2\tau_i}{a}$$

As the balance of shear force is written:

$$\tau = \frac{a\tau_i}{a}$$

You can find the familiar expression of the shear interface:

$$\tau_i = \frac{G_m}{a\log\left(\frac{R}{a}\right)} \quad [W_R - W_a]$$

The equilibrium in linear thermo elasticity gives:

$$\begin{cases} \frac{dW_R}{dx} = \varepsilon_m = \varepsilon_1 + \frac{\sigma_m}{E_m} + \Delta\theta\alpha_m & si\ r = R \\ \frac{dW_a}{dx} = \varepsilon_f = \frac{\sigma_f}{E_f} + \Delta\theta\alpha_f & si\ r = a \end{cases}$$

where $\varepsilon, E, \alpha, \Delta\theta$

Are respectively the strain, Young's modulus, coefficient of thermal expansion and the temperature difference. Indices "and" spot sizes on either the fiber or the matrix, which can describe the equilibrium thermo elastic system by the following differential equation:

$$\frac{d^2\sigma_f}{dx^2} = -\beta^2\left[\varepsilon_1 + \frac{\sigma_m}{E_m} + \frac{\sigma_f}{E_f} + (\alpha_m - \alpha_f)\Delta\theta\right] \quad (6)$$

With:

$$\beta^2 = \frac{2G_m}{a^2\log\left(\frac{R}{a}\right)}$$

And considering the equilibrium condition follows:

$$V_f\Delta\sigma_f + (1 - V_f)\Delta\sigma_m = 0$$

We get:

$$\frac{d^3\sigma_f}{dx^3} = \beta^2\left[\frac{V_f}{(1-V_f)E_m} + \frac{1}{E_f}\right]\frac{d\sigma_f}{dx}$$

By asking:

$$n^2 = \beta^2\left[\frac{V_f}{(1-V_f)E_m} + \frac{1}{E_f}\right]$$

The general form of duress arises:

$$\sigma_f(x) = \left[\frac{(\alpha_m-\alpha_f)\Delta\theta+\varepsilon_1}{\frac{V_f}{(1-V_f)E_m}+\frac{1}{E_f}}\right]\left(1 - \frac{\cosh(nx)}{\cosh(nL)}\right)$$

3. Use of COMSOL Multiphysics

Based on the model of Cox [7]:

$$\sigma_{f\,(x)} = \varepsilon E_f\left[1 - \frac{ch(\beta X)}{ch(\beta L)}\right]$$

$$\sigma_{moy} = E_c\varepsilon$$

Where: $\varepsilon, E, \alpha, \Delta\theta$ Haut du formulaire

Homogenized through Comsol multiphysics, the Behavior of the composite by simulating a tensile test, a square matrix composite :

$1 * 1 * 10^{-2}$;

Surrounding a fiber of radius : $r = 0.1$

Boundary conditions :

$u_y = 1mm;$

Upper horizontal boundary: u=0 down.

The lateral boundaries are free.

After integration over the border from the top, there is the pulling force; where the Young's modulus of the homogenized material.

It has automated this with Matlab to view Figure 4, the influence of the volume fraction of reinforcement.

4. Figures

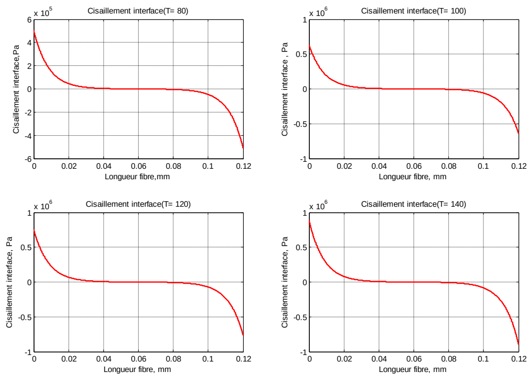

Figure1. Influence de la température sur la contrainte.

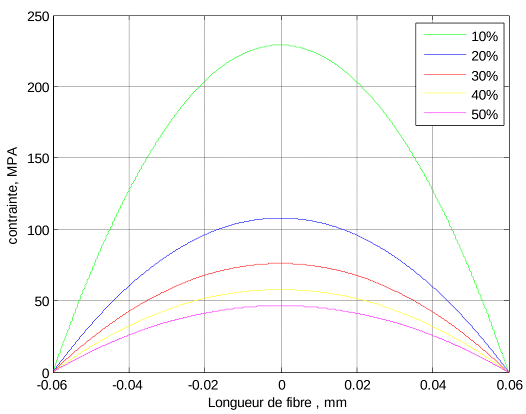

Figure2. Influence de la fraction volumique sur la contrainte.

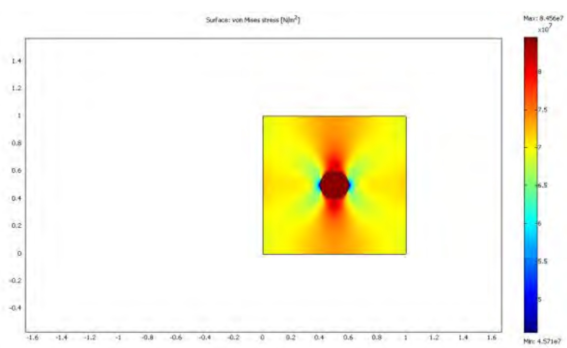

Figure3. Simulation pour r=0.1mm

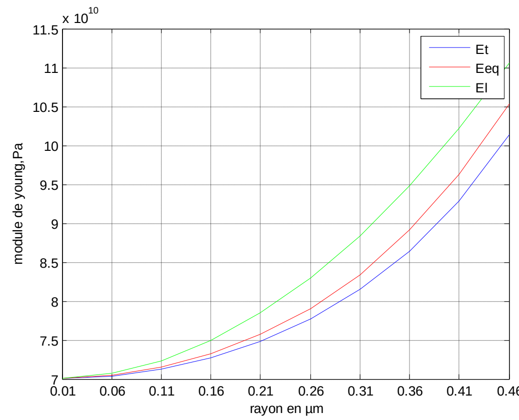

Figure4. Modules de Young équivalent

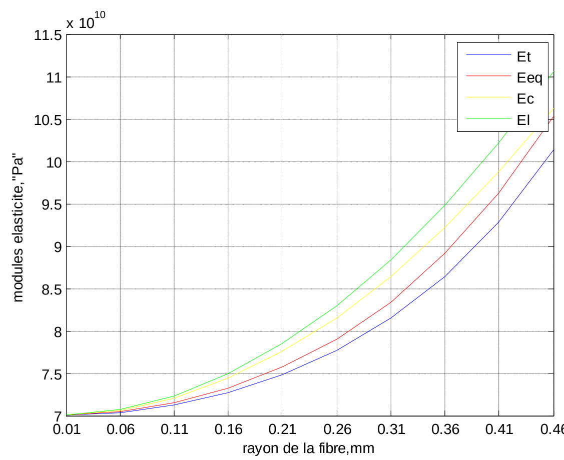

Figure5. Modules de Young Moyens

5. Equations

$$\begin{cases} \frac{dW_R}{dx} = \varepsilon_m = \varepsilon_1 + \frac{\sigma_m}{E_m} + \Delta\theta\alpha_m & si\ r = R \\ \frac{dW_a}{dx} = \varepsilon_f = \frac{\sigma_f}{E_f} + \Delta\theta\alpha_f & si\ r = a \end{cases}$$

$$\frac{d^3\sigma_f}{dx^3} = \beta^2 \left[\frac{V_f}{(1-V_f)E_m} + \frac{1}{E_f}\right] \frac{d\sigma_f}{dx}$$

$$\sigma_f(x) = \left[\frac{(\alpha_m - \alpha_f)\Delta\theta + \varepsilon_1}{\frac{V_f}{(1-V_f)E_m} + \frac{1}{E_f}}\right]\left(1 - \frac{\cosh(nx)}{\cosh(nL)}\right)$$

$$\tau_i(x) = \frac{a\beta^2}{2n}\left[(\alpha_m - \alpha_f)\Delta\theta + \varepsilon_1\right]\left(\frac{\sinh(nx)}{\cosh(nL)}\right)$$

$$\tau_{max} = \frac{a\beta^2}{2n}\left[(\alpha_m - \alpha_f)\Delta\theta + \varepsilon_1\right]\tanh(n\frac{l}{2})$$

7. Conclusion

It is recognized that the mechanical behavior of composites depends strongly on the fiber-matrix interface. The mechanical behavior of the interface depends on several parameters of its components, fiber or matrix.

It was noted the influence of curing temperature on the behavior of the fiber-matrix interface. It is clear that the volume fraction of reinforcement contributes to the model found that the value of time is involved in the equation mathematique. La the simulation shows. Our study led us to conclude that the percentage and type of reinforcement must be properly valued and play an important role in the behavior of the interface

8. References

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