THE EFFECT OF THE MORPHOLOGY ON THE MECHANICAL AND INTERFACIAL PROPERTIES OF VAPOUR GROWN CARBON FIBRES

F. W. J. van Hattum,[1] *Ph. Serp,*[2] *J. L. Figueiredo,*[2] *A. Madroñero*[3] *and C. A. Bernardo*[1]
[1] *Departamento de Engenharia de Polímeros, Universidade do Minho, 4810 Guimarães, Portugal*
[2] *Lab. de Catálise e Materiais, Fac. de Engenharia, Universidade do Porto, 4099 Porto, Portugal*
[3] *Centro Nacional de Investigaciones Metalúrgicas, Avda Gregorio del Amo 8, 28040 Madrid, Spain*

Introduction

As a result of the production method, Vapour Grown Carbon Fibres (VGCF) can present a wide variety of shapes and diameters, which reflect their internal structure [1, 2]. To determine the mechanical properties with sufficient accuracy it is necessary to know the geometrical characteristics of the fibres. In a previous work [3], seven different morphologies in which VGCF can be produced were identified. In the present work, two batches of VGCF in which three of the morphologies predominated were studied to determine the effect of the shape on the mechanical and interfacial properties.

Experimental

Several batches of VGCF were produced in our laboratories, for which the experimental details can be found in references [4-5]. From these, two batches were selected for further studying. The first batch contained 'perfect cylinder' VGCF, the second batch contained 'quasi-perfect cylinder' VGCF and the related 'crenulated' VGCF. SEM micrographs of a 'perfect cylinder', a 'quasi-perfect cylinder' and a 'crenulated' fibre are shown in figures 1a) through 1c). A statistical analysis based on detailed SEM observations of the second batch led to approximate values of 50% and 45% for the 'quasi-perfect' and 'crenulated' fibres, respectively and a minor proportion of other VGCF morphologies. As the fibres are very fragile, it is very difficult to separate the two morphologies prior to testing. It was thus decided to test them together. The diameters of the two batches of VGCF were measured using a laser diffraction technique [3]. Tensile properties of the two batches of VGCF were determined according to ASTM D 3379-89, at room temperature, in an Instron 1122 universal testing machine with a 1N load cell. For each batch 4 different gauge lengths were tested (appr. 15, 20, 30 and 40 mm), 15 fibres at each gauge length, using a cross-head speed of 0.5 mm/min. In this way, the dependence of the tensile properties on both the length and the diameter was determined. Fragmentation tests on monofilament composites [6] were performed, to determine the interfacial properties.

Results and Discussion

The aggregated values of the diameters and the tensile modulus determined for the two batches are given in table 1. A decrease in tensile modulus from 'perfect cylinder' to 'quasi-perfect cylinder/crenulated' can be observed. Furthermore, for both batches, the decrease of the tensile modulus of VGCF with fibre diameter was observed, as previously reported [7]. Using similar data obtained by Tibbetts [2] it can be argued that the present difference in the moduli between 'perfect cylinder' and 'quasi-perfect cylinder/crenulated' can be attributed to the difference in the mean fibre diameter between the two batches. This means that the tensile modulus is not significantly affected by the fibre morphology. For both batches the Weibull distribution was successfully used to describe the length-dependence of the fibre tensile strength. Almost all experimental results fall within the 90%/95% confidence limit of the distributions for 'perfect cylinder' and 'quasi-perfect cylinder/crenulated'. Figure 2 shows the combined effect of both diameter and gauge length on the strength, evidentiated through a smoothed weighted average surface fit on the tensile data. The fit of the 'perfect cylinder' data corresponds to the upper surface and that of the 'quasi-perfect cylinder/crenulated' to the lower surface. The overall dependence of tensile strength on both fibre diameter and length is qualitatively similar for all fibre shapes, albeit quantitatively dependent on the fibre morphology. The fragmentation test proved to be unsuitable for determination of the interfacial properties of both batches. Due to the layered structure and the inherent failure mode of VGCF - the core of the fibre is being pulled out of the outer layer like a sword from its sheath - it is impossible to measure the fragment lengths required to determine the interfacial shear stress. Furthermore, the fragmentation test theory assumes that the force transmission between fibre and matrix occurs at the fibre-matrix interface. In the present case, this transmission is more complex and impossible to quantify.

Conclusions

From the work presented it can be concluded that the shape of vapour grown carbon fibres has a small influence on the value of the tensile modulus. However, fibres with shapes different from perfect cylinders, have a lower tensile strength. The fragmentation method cannot be used for interfacial characterisation of VGCF.

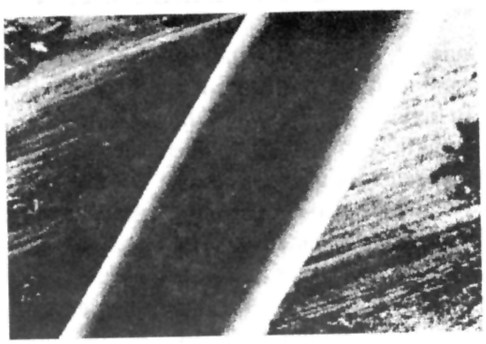
Acknowledgements

This work was supported by the European Economic Community, through the Human Capital and Mobility Program, under Grant Number CHRXCT940457. Two of the authors, FWJVH and PhS, acknowledge the personal grant received under the same contract.

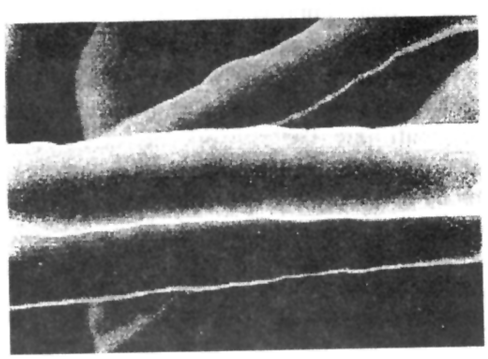
Fibre morphology	Fibre Diameter (μm)				Modulus
	Mean	St. Dev.	Max.	Min.	(GPa)
'Perfect cylinder'	11.7	3.2	20.7	4.4	140
'Quasi-perfect cylinder/crenulated'	18.3	2.0	24.8	10.7	110

Table 1. Diameters of 2 batches of VGCF with different shapes.

a)



b)



c)

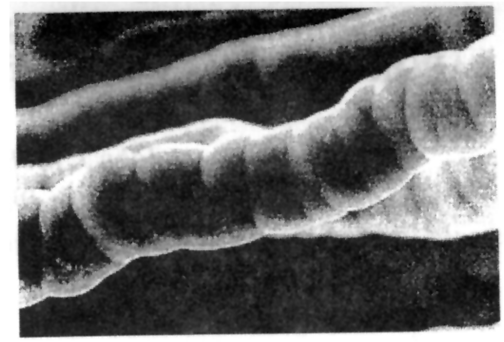


Figure 1. Different shapes of Vapour Grown Carbon Fibres. a)'Perfect cylinder'; b)'Quasi-perfect cylinder'; c) 'Crenulated'.

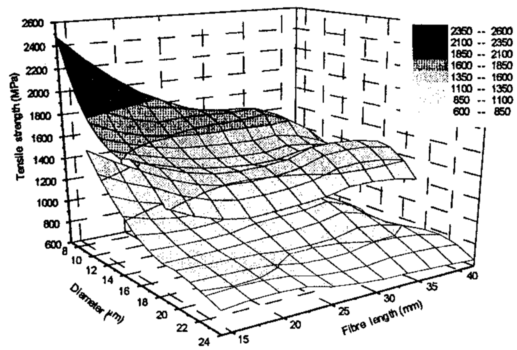


Figure 2. Three-dimensional plot of the fibre strength as a function of gauge length and average fibre diameter for both 'Perfect cylinder' and 'Quasi-perfect cylinder / crenulated'.

References

1. Madroñero, A., *Materials Science and Engineering*, 1994, A-105, L1.
2. Tibbetts, G.G., in *Carbon Fibers, Filaments and Composites*, ed. J.L. Figueiredo, C.A. Bernardo, R.T.K. Baker and K.J. Huttinger. Kluwer Academic Publishers, Dordrecht, 1990, p. 73.
3. Van Hattum, F.W.J., Benito-Romero, J. M., Madroñero, A. and Bernardo, C. A., *submitted to Carbon.*
4. Serp, Ph. and Figueiredo, J.L., *Carbon*, 1996, **34**(11), 1452.
5. Madroñero, A., *A Reactor for the Production of Short Ceramic Fibres from Gas*, Int. Publication number WO 93/17159 (02.09.93 93/21).
6. Paiva, M.C., Nardin, M., Bernardo, C.A. and Schultz, J., *Composites Science and Technology*, in press.
7. Tibbetts, G.G. and Beetz, Jr., C.P., *Journal of Physics D: Applied Physics*, 1987, **20**, 292.