Composite Engineer's Viewpoint

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Designing with Composite Materials
Part 2 – Materials Selection and Processes

The selection of materials to be used in the composite, i.e. the fibre and the resin system, and the manufacturing process to form the structure are most critical in the development of the final composite engineering and physical material properties. The fibres generally hold the key to the majority of the properties. There is a wide range of fibres to select from, but generally, the end result comes down to cost, weight and performance. Figure 1 shows the general stress/strain relationship between several common fibre types. The fibres also come in a number of forms, i.e. continuous unidirectional, woven cloth or short fibre mat. Each form represents a different level of achievable properties. The most efficient fibre form (weight vs. performance) is the continuous unidirectional, then followed by woven cloth and last the short fibre mat. The effect of fibre form is illustrated through the achievable fibre volume ratio and relative performance, see below.

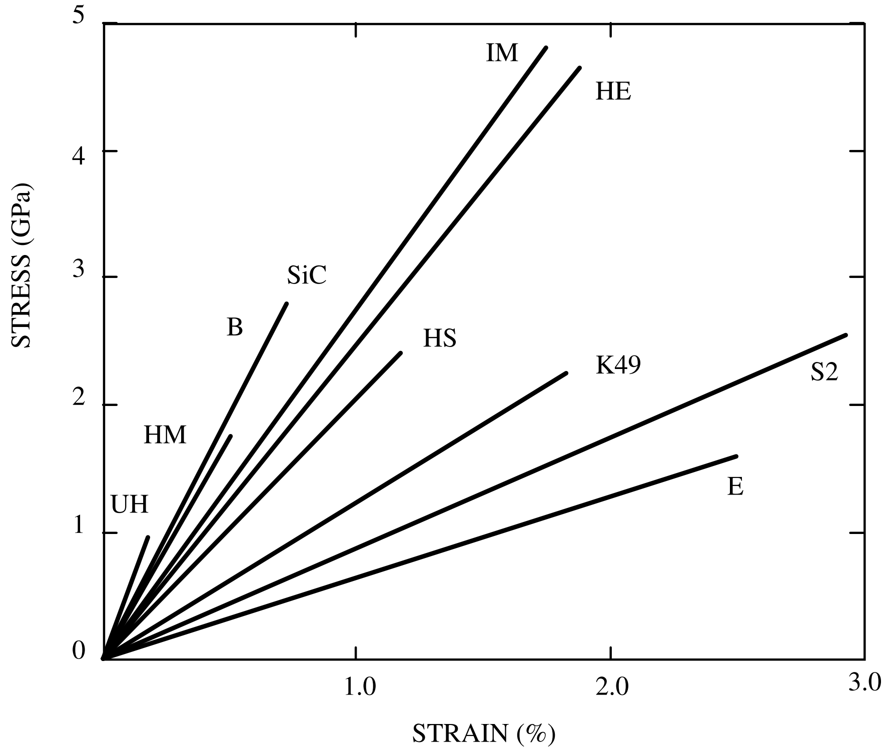

Table 1: Fibre Stress/Strain Behaviour

The resin system is used to bind, protect and assist the fibres with load transfer. Based on a simple micromechanics rule of mixtures approach the two major properties (axial strength and stiffness) of the composite structure are proportional to the fibre properties and the fibre volume ratio. The typical aim is to have both a high fibre stiffness and fibre volume ratio for structural efficiency. During the process of composite structure fabrication, the fibre volume ratio is dictated by the removal of excess resin. As the fibre volume ratio changes there is a proportional change in the mechanical and physical properties of the composite structure. Thus, to achieve a specific engineering deflection (stiffness dominated) or load bearing capacity (structural strength) for example, a reduced relative stiffness due to fibre form, or a reduced strength because of a low fibre volume ratio will require a thicker section to be made. Noting that the higher performance fibres are generally lighter than the matrix, then combined with an overall larger cross-section dimensions you have a heavier structure. This is also directly related to a higher cost in terms of materials and labour. Cost estimate will be covered in a future article.

The following table clearly shows this effect with stiffness efficiency.

$$\text{Stiffness Efficiency Index} = \frac{Stiffness\ Index\ x\, V_f}{V_f\,(Uniaxial)}$$

	STIFFNESS INDEX	**MAXIMUM V_f**	**STIFFNESS EFFICIENCY INDEX**
AXIAL	1.00	0.70	1.00
BIAXIAL (Balanced)	0.50	0.60	0.42
RANDOM (Planar)	0.30	0.35	0.15
RANDOM (3D)	0.12	0.30	0.05

The selection of the manufacturing process, and there are several to choose from, will be dependent of equipment availability, cost, time, materials selection, product quantity, for example. However, whatever process is selected, the development of composite material properties will be based on ply or fibre orientation and the fibre volume ratio.

Your choice of fibre type, fibre form, resin system and manufacturing process will determine the composite material properties … as the Knight protecting the Holy Grail said to Indiana Jones, in the movie, 'The Last Crusade', "**choose wisely**".

In the next article, we will see how you can determine the number of plies required in various orientations to meet the structural properties of the structure. I also welcome questions, comments and your point of view. Feel free to contact me via r.heslehurst@adfa.edu.au. I may publish your questions and comments, and my response in future newsletter.