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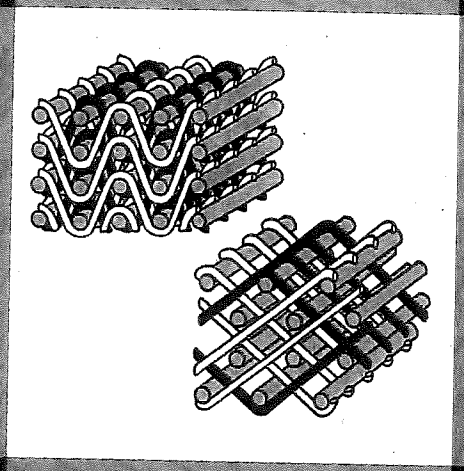

3-D fibrous assemblies

Properties, applications and modelling of three-dimensional textile structures

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Introduction to three-dimensional fibrous assemblies

Abstract: Three-dimensional (3-D) textiles are those materials that have a system or systems in all three axes of plane. These materials offer particular properties, such as interlaminar shearing force, mechanical and thermal stability along all three axes of space, that are not achievable with other reinforcements. The development of three-dimensional textiles has taken place rapidly over the past two decades. It can be credited largely to the growth of another technology: composite materials, which combine fibres and a matrix. An understanding of the production methods and structures of these 3-D fibrous assemblies would go a long way in design, process control, process optimization, quality control, clothing manufacture and development of new techniques for specific end uses. This chapter introduces various 3-D woven, knitted, non-woven, braided and stitched fabrics with their brief description and advantages.

Key words: three-dimensional (3-D) textiles, 3-D woven fabrics, 3-D knitted fabrics, 3-D non-woven fabrics, 3-D braided fabrics.

1.1 Introduction: concepts of three-dimensional fibrous assemblies

Textile structures such as in woven, knitted, non-woven and braided fabrics are being widely used in advanced structures in the aerospace, automobile, geotechnical and marine industries. In addition, they are finding wide application as medical implants such as scaffolds, artificial arteries, nerve conduits, heart valves, bones, sutures, etc. This is because they possess outstanding physical, thermal and favourable mechanical properties, particularly light weight, high stiffness and strength, good fatigue resistance, excellent corrosion resistance and dimensional stability. In addition, they act as attractive reinforcing materials in various composite applications with low fabrication cost and easy handling (Tan *et al.*, 1997). With high-end applications such as in aerospace, the orientation of the fibrous reinforcement is becoming more and more important from a load-bearing point of view, as is the need for placing the reinforcement oriented in the third dimension (Alagirusamy *et al.*, 2006).

Textile fabrics, termed preforms in composites and other applications, consist of various reinforcing fabrics such as wovens, knits, braids and

non-wovens. Two-dimensional fabrics have allowed us to drape bed, board and body in a profusion of texture, pattern and colour over the centuries. The development of advanced fibres has led engineers to consider textiles for high-performance applications such as in construction and aeronautics. These fabrics have been relatively well developed in terms of production, analysis and application and some of them have long been used in structural composite fields (Chou and Ko, 1989; Mohamed, 1990). However, the strength of these traditional fabrics is anisotropic, manifesting itself primarily in the direction of the fibre orientations. Most of these 2-D textile structures retain the inherent weakness of laminated composites that are susceptible to delamination.

To extend the use and value of textiles into industrial and engineering applications, which typically require strength in more than two directions, textile designers have bound together layers of textiles and exploited the chemical properties of fibres and binders to create novel non-woven textiles whose fibres are not restricted to two-dimensional arrangements. More recently, they have taken the next step: finding ways to manufacture true three-dimensional (3-D) textiles. Hence, 3-D fabrics have been introduced to respond to the needs of a number of industrial requirements such as composites capable of withstanding multidirectional stresses.

The development of 3-D textiles has taken place rapidly over the past two decades. It can be credited largely to the growth of another technology: composite materials, which combine fibres and a matrix. Textile engineers have been challenged to develop strong fibre architectures and new manufacturing processes for building textile structures in three dimensions, as these 3-D fabrics hold great promise for use in industry, construction, transportation and even military and space applications. They are often made into a near net shape so that the overall manufacturing cost can be very low for certain applications (Mohamed, 1990).

An understanding of the production methods and structures of these 3-D fibrous assemblies would go a long way in the design, process control, process optimization, quality control, clothing fabrication and the development of new techniques for specific end uses. The interrelationship between their structure and various properties may be of great help in designing new types of 3-D structures for the construction, medical, sports and aerospace industries.

1.2 Two-dimensional structures (two-dimensional fabrics)

1.2.1 Two-dimensional wovens

Weaving is the most widely used textile manufacturing technique and accounts for the majority of the two-dimensional (2-D) fabric produced

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