3D WOVEN FABRICS FOR ADVANCED COMPOSITES

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Abstract: *The role of 3D fabrics in advanced textile composites has gained significant attention due to their ability to enhance structural integrity, mechanical performance, and design versatility. Unlike traditional 2D laminates, 3D woven fabrics offer improved interlaminar strength, damage tolerance, and resistance to delamination, making them ideal for high-performance applications in aerospace, automotive, and defence industries. This paper explores the various research carried out in 3D fabrics for making advanced textile composite.*

Keywords: *3D Weaving, Advanced Composites, Interlock Weaving, Lightweight Structures*

1. Introduction:

3D Weaving: 3D weaving is an advanced textile manufacturing technique where fabrics are woven in three dimensions instead of the traditional two-dimensional structure. Unlike conventional weaving, where warp and weft are interlaced in a single plane, 3D woven fabrics integrate multiple layers of yarns, creating a more complex, interconnected structure.

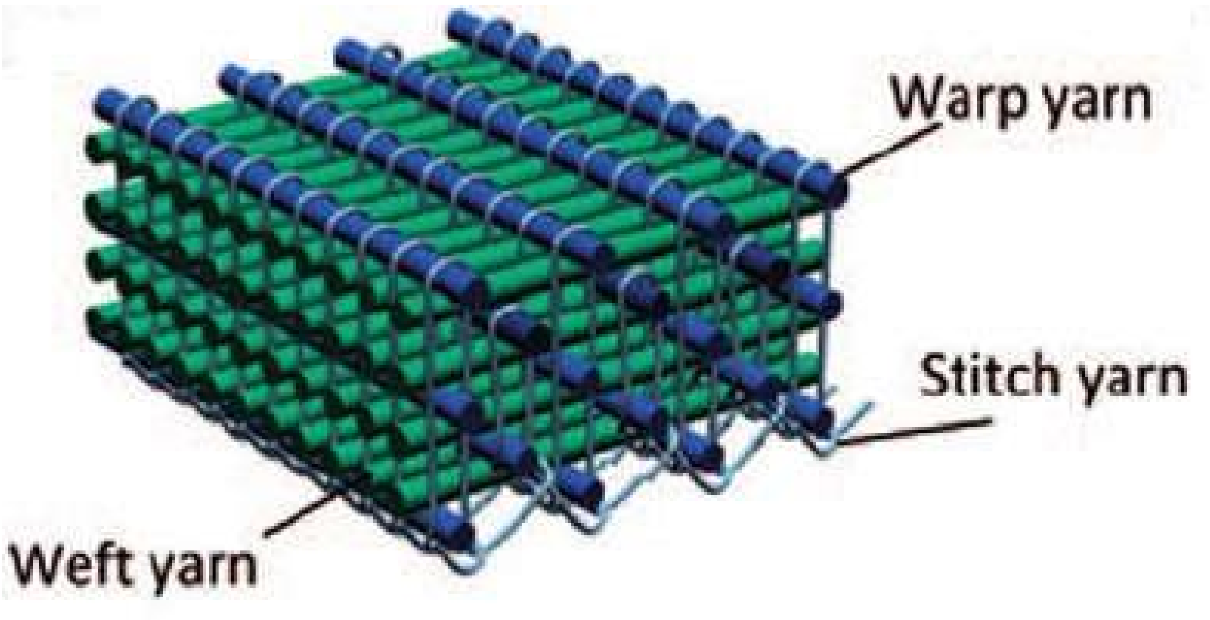

Figure 1. 3D Fabric

Composite: Composites are engineered materials made from two or more constitute materials with significantly different physical or chemical properties that when combined produce material with characteristic different from individual components.

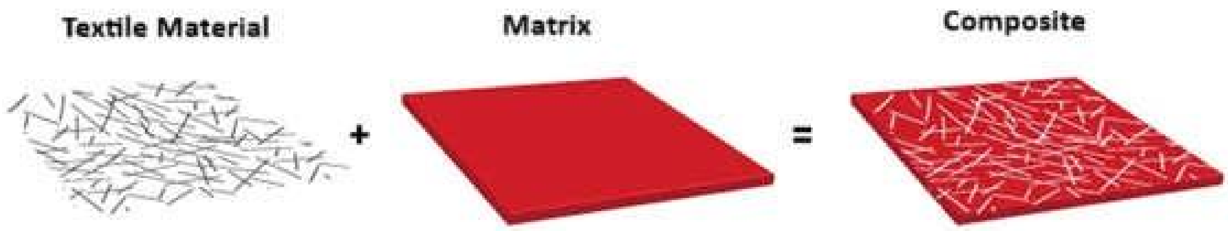

Figure 2. Composite

Importance of 3D Woven Fabric in Composite: 3D woven fabrics are crucial in composites due to their superior mechanical properties, such as higher flexural, tensile, and compressive strength. Their structure eliminates in-plane crimp, enhancing load distribution and durability. Additionally, they improve manufacturing efficiency by reducing labour time, as fewer 3D plies replace multiple 2D layers. These benefits make them ideal for high-performance applications in aerospace, automotive, marine, and ballistic sectors.

2. Research carried out in 3D fabrics for advanced composites

The use of 3D fabrics in advanced composites revolutionizes material performance by enabling complex geometries, reducing delamination, and improving mechanical properties, thus driving innovation in lightweight and durable composite structures.

B K Behera and Rajesh Mishra's [1] research explores 3D woven fabrics, produced by modifying conventional weaving mechanisms for specialty industrial applications in construction, automotive, ballistic, and marine sectors. These fabrics create high-performance composite preforms, offering superior mechanical properties like flexural, tensile, and compressive strength due to reduce in-plane crimp. Additionally, 3D weaving enhances efficiency, minimizing labour time by replacing multiple 2D layers with fewer 3D plies. Khokar's 3D weaving process introduces dual-directional shedding, enabling network-like fabric structures. This innovation allows preforms of any shape to be cut from a fabric block, improving efficiency, material utilization, and overall production economy in industrial applications.

R G Panneerselvam et.al [2] studied a novel Orthogonal Weft Tapestry (OWT) weave, combining orthogonal and weft tapestry structures to develop innovative compound weaves. A new figured fabric structure, "Figured - Face Flip Face - Fabric (FFFFF)," is also analysed, focusing on weaving methodologies using electronic and mechanical jacquard looms. Techniques like guide graph superimposition, double punching, and techno-ergonomics are explored. The study demonstrates that FFFFF fabric can be efficiently woven using self-stitched double cloth and OWT weaves, with the latter offering superior quality across finer, medium, and coarser ranges. Computer-aided graph designing simplifies jacquard loom settings, drafting, and graph punching, enabling the development of innovative reversible textiles such as shawls, jackets, carpets, and curtains. This research also lays the foundation for advancements in shedding, picking, and weaving techniques, expanding possibilities for future textile developments.

Ogale Vinayak & Alagirusamy, R [3] have their study explores textile preforming operations and their role in composite manufacturing, emphasizing modifications in yarn and fabric formation to enhance cost-effectiveness, fiber orientation, and near-net shaping. It critically reviews advancements, advantages, and challenges, focusing on their impact on composite mechanical properties. While 2D preforms are widely used, 3D preforms offer superior performance, particularly in aerospace and defence. Advancements in textile preforming enable cost-effective composite production, but further research is required to develop efficient methods for manufacturing complex 3D textile preforms for broader industrial applications.

Potluri P et.al [4] studied the role of technical textiles in fiber-reinforced composites, focusing on their high-value engineering applications. It highlights the adaptation of traditional textile machinery for 2D reinforcements and the need for novel machines for 3D textile preforms. The research evaluates the limitations of traditional methods and explores robotic preforming as a solution for complex near-net preforms using dry fibers. This approach enhances efficiency, reduces costs compared to prepreg systems, and holds strong potential for commercial viability with further advancements.

Mário Lima et.al [5] in their study focus on developing a multiaxial 2D interlaced woven structure that provides strength in four directions by inserting bias yarns at 45° between the warp and weft. A new weaving system was designed, integrating warp and bias yarn feeding, criss-cross insertion, shedding, and beating-up mechanisms. The mechanical performance of HT polyester, aramid, carbon, and glass fiber structures was evaluated, highlighting improved resistance to mechanical loads and delamination. The study validates the multiweave concept for aerospace and marine applications, with potential to replace traditional multi-layered fabrics, enhancing reinforced composites with improved strength and isotropic behavior.

Kaldenhoff, R & Wulfhorst, B [6] have studied cost-effective methods for producing fiber-reinforced composites using hybrid yarns created through friction spinning. It examines 2D textile preforms (knitted multiaxial layers, woven narrow fabrics) and 3D fiber reinforcements using advanced knitting and 3D rotational braiding. The research evaluates textile technologies for composite reinforcement, focusing on efficiency, structural integrity, and eliminating additional laying processes. It highlights cost reduction through textile optimization, emphasizing fiber orientations tailored for composite demands. The findings demonstrate the high potential of advanced textile structures in developing lightweight composites with superior mechanical properties.

Turan, R B & Okur [7] in their study focus on developing realistic 3D models for 2/1 and 3/1 twill weaves, considering structural parameters like fabric settings and yarn linear density. The inherent skewness in twill fabrics is analysed using the B-spline method to define smooth 3D yarn paths. Theoretical crimp factors and mass per unit area are compared with experimental results, confirming model accuracy. Visual 3D simulations validate the model for textile applications. The close match between theoretical and measured crimp factors ensures reliable simulations, making these models valuable for textile analysis and computer applications.

Minapoor Shohreh et.al [8] in their study investigate the bending behavior of 3D orthogonal carbon weave composites using a three-point bending test. It examines the effects of carbon fiber tow type, yarn insertion density, and longitudinal yarn tension on fiber volume fraction and bending properties. Results indicate that increasing weft and warp yarn density and longitudinal yarn tension enhances fiber volume fraction and bending modulus, while additional carbon tow monofilaments have minimal impact. Bending rigidity is primarily influenced by carbon tow type, followed by warp and weft insertion density, and then longitudinal yarn tension, identifying key factors for improved bending performance.

Chang-Hsuan Chiu & Chao-Chuan Cheng [9] studied the weaving method for producing 3D I-shaped and double-cross-shaped woven preforms for advanced composites. By modifying conventional weaving mechanisms with multi-eye heddles, warp yarns are divided into three sections, allowing the formation of mainframes and flanges. The preforms are initially woven flat and later unfolded into near-net-shape constructions. A creel system facilitates let-off motion, while rollers replace the traditional cloth roller, enhancing weaving efficiency. The research examines single-layer and tri-layer fabric structures, analyzing their structural formation and suitability for composite applications.

Hassan M., El-Dessouky and Mohamed N. Saleh [10] have studied the 3D woven preforms for fiber-reinforced composites, emphasizing their advantages over traditional 2D fabrics in composite manufacturing. They examine 3D weaving techniques, composite fabrication, and mechanical performance, particularly in automotive applications. A cost-effective standard loom with a Dobby shedding system was used to weave 3D complex architectures, and RTM composite laminates were void-free. Mechanical testing revealed higher tensile and flexural strength in the weft direction due to lower crimp. Twill and satin fabrics exhibited superior load resistance, and a final fabric with multiple weave zones successfully conformed to an RTM tool for automotive parts.

Conclusion:

3D fabrics play a key role in advancing textile-based composites by offering enhanced structural integrity, superior mechanical properties, and greater design flexibility. By integrating advanced weaving technologies and innovative material combinations, 3D fabrics are paving the way for next-generation composites with tailored properties to meet the demands of modern engineering challenges.

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