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A Review of Some Innovative Concepts In The Weaving of Technical Fabrics

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Abstract

The article comprehensively reviews some significant researches in the weaving of functional fabrics. Conventional 3D woven T-shaped preforms were modified for improving joint/peel-off strength of associated T-shaped polymeric composites. Preforms were modified at weaving level by preferred yarns orientations for better performance in associated composites. Major modifications studied are; the addition of supporting layer, single or double-crossing in joint layers, and crossing along with supporting layer (in a single sample). The tapered circular tubular (TCT) woven fabric has been applied successfully as the components in vascular prostheses. The application of tapered tubular woven fabric based on the existing weaving technology requires the densification of a large end to ensure porosity uniformity through the tapered tubule. Although the previously proposed equal-cover-factor (ECF) design technique overcame some disadvantages of the conventional densification methods, such as the protruding portions of the dropped yarns as well as the change of both fabric porosity and tensile strength, the off-loom weft density significantly deviates from the on-loom value.

Keywords: *Polymeric composites, Weaving, 3D woven, T-shaped preforms; Tapered, Tubular.*

I. Introduction

The demand for high specific strength, fiber-reinforced polymeric composite materials is growing drastically in aerospace, marine, automotive, supports in biomedical and ballistic protection applications, etc. Woven fabrics are the first choice as a reinforcement for such high-tech applications due to their high structural stability and strength amongst all textile structures[1].In the case of 2D fabris the fabric thickness is insignificant in relation to the length and width. Two series of yarns are involved in the formation of 2D woven fabrics, of which one is the warp (running longitudinally and weft (running laterally). 2D woven fabric-based composites have captured a wide area of applications due to their ease of processing in both reinforcements as well as composite fabrication[2]. But low tolerance to a high-impact load, shear load, and vibrations limit the applications of 2D laminates, especially in the applications where delamination is critically affecting the performance[3,4].

In the design of different tubular-shaped products, weaving is usually an adopted technique. During the past 3 decades, the automatic production method has been effectively developed for cylindrical grafts, particularly with regard to medium and large caliber vascular prosthesis. However, the blood vessels were early seen as tapered tubules with a variable diameter along their longitude direction and a taper angle of about1° ~3° [5,6]. Moreover, hemodynamic studies showed that such a small angle has considerable influence on the vascular wall property and organic reaction, especially the flood flow distributions along axial of tapered vascular[7-12]. The TCTwoven structure is typically utilized as the key component in cardiovascular surgeons for repairing portions of the cardiovascular system, including but not limited to all or portions of the ascending aorta and aortic root[13,14].

II. Weaving of modified 3d T shaped woven composites

To avoid these issues and complex shaping, the 2D fabric is passed through a cut and stitch process by which delamination is significantly reduced[15]. However, such types of shaped preforms are not only laborious and machine intensive, but the chances of defects, fabric wastage, time, and energy consumption are also increased[16]. Also, a number of factors could be attributed to shifting the shaping process to the loom/weaving stage, such as discontinuity of yarns in the whole structure, fiber damage by needle, and improper resin infusion in the seam area. By on-loom (3D) shape weaving, the yarns are continuous at the joints, thus rendering high strength with the short and stable process of manufacturing[17].3D woven fabrics are placed in a separate class from 2D fabrics due to their significant difference in thickness[18]. For the development of 3D woven fabrics, the specialized loom was introduced, which can handle three sets of yarns at the same time, i.e., longitudinal yarn (X), transverse yarn (Y), and vertical yarn (Z)[19,20]. But, owing to economical limitations, their commercial viability continues to be restricted. Multilayered 3Dwoven structures provide an option and hold promise in the design of high-performance preforms by a low cost and high-speed conventional weaving process. Basic principle governing multilayered shaped preforms is drawing-in in multiple layers of yarns through the loom in the foldedstate[21]. Based upon the ultimate shape necessary, chosen layers are stitched on a loom by modifying weave design in a particular area, and certain areas are set unstitched. The doffing of the fabric from the loom is followed by unfolding and designing the required composite shape. A single web can be formed by stitching all layers on a loom resulting in the formation of T-shaped fabrics that forms joint of composite. Flanges are formed by an equal division of the web that has no stitches between the two halves (Figure 1).

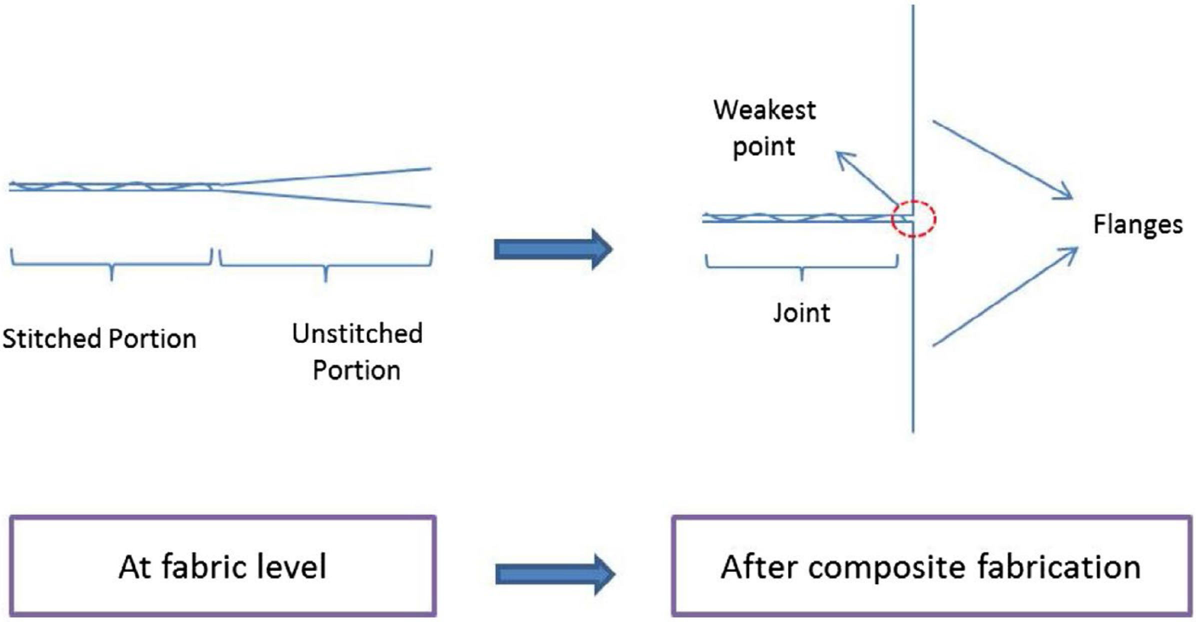

Figure 1. 3D woven T-shaped fabric stitched on loom[28]

A number of aerospace components that include spars, wings (to avoid buckling under load), wind turbines blades (fatigue resistance), and boat bodies, are made from T-shaped composites are employed intensively as stiffeners and joints in aerospace applications. Flanges are interfaced with the skin, and they are web provides backing and bending resistance[22,23]. The T-shaped composites suffer from peel-off failure resulting from the stresses under practical applications. Hence, the all-around performance of the joint and stiffener is governed by the peel-off strength of the T joint. In the case of wind turbine application, the T-shaped stiffeners have been investigated, and the fatigue resistance is considered crucial. With regard to static and fatigue loads, the comparison has been made on various 3D geometrics. In order to predict the generation of crack and propagation behavior, a model has been evolved and has lead to the conclusion that the point where flanges intersect has the highest susceptibility to failure. In the case of T-shaped composites used in small boats, similar results for the failure mode of T joints have been analyzed. Transverse stitching has been suggested for enhancement of the strength of this portion. It has been found that there has been a considerable enhancement in flexural and tension properties. Currently, natural fibers reinforced composites are the focus of research because of their best cost to performance ratio, environment friendliness, biocompatibility, and biodegradability[24]. Natural fiber reinforced-shaped composites with different 3D woven structures were compared in our previous work[25].

The findings related to peel-off strength have revealed that T-shaped composites having layer-to-layer stitching patterns possess better mechanical properties in comparison with through-thickness stitching patterns. The weakest point that is most prone to crack generation is found to be the interface where the web splits into two(encircled red in Figure 1). Upon examination, it is found that the total strength of the T-shaped composite equals the strength of the joint (weakest point) where two layers are joining with one another. In order to enhance the total performance of T-shaped composites, this joint strength needs to be enhanced. In all possibilities, there have been no alternations made in the preforms so as to improve the strength in the joint area. This major emphasis has been towards the addition of extra supporting continuous (through the flanges)layer, the crossing of layers on joint point, and the combined effect of both modifications in a single sample to improve joint strength. The strength of the joint has therefore been enhanced by means of crack generation and propagation resistance of modified. In order to obtain high-strength structures in an economical way, alteration of yarn architectures offer an easy option. A homogenized structure (S-H) having single yarn in all threesides was also made as reported previously as a controlled sample[26,27]. Despite the fabrication of this structure earlier, its comparison with other structures, impact properties, and peel-off (of single-layer composite) have not been investigated so far.

The production and characterization of 3D woven T-shaped preforms and related proxy-based composites have been done. During the weaving process, fundamental weave designs have been adopted with modification and special layer-wise arrangements for the production of T-shaped preforms. The stitched T-shaped composites in loom state exhibit 38% greater peel-off strength in comparison with unstitched 3D woven fabric-based composites. However, in the case of unstitched composites, specific impact energy absorption has been found to be high. The addition of a supporting layer increases peel-off strength by 15% and impact strength by 18.51%. Single and double-crossing between layers reduces the peel-off strength by 5.1 and 1.03%, respectively, but impact strength is improved up to 18.51 and 44.4%, respectively[28]. It has been found lower tensile strength and elongation results from the locking of yarns due to their crossing get locked by crossing. The greater resistance of the crossed structure to crack generation and greater stiffness result in greater impact resistance. The single crossed structure along with the supporting layer is considered the best variation for lower elongation, higher peel-off strength, and impact energy absorption. Supporting layer and crossed layer yarns resist against stress together (for lower elongation of both structures), thus increasing joint strength synergistically.

III. Weaving of tapered circular tubular woven graft

Conventional techniques of forming TCT woven structures are manually cut and suture multiple standards are woven tubular structures into required size and shape, or keep constant warp density and change the number of warp yarns, or keep the total number of warp yarns and change the warp yarn density[29,30]. Single fabrics having various can be woven and stitched together to form a complete tubule by means of the cutting and suturing method.

During the past few years, continuous flat-weaving methods have been used to achieve a change of graft diameter eventually. During the process of weaving, the tubular sections with different shapes have been produced from gradual changes in the number of warp ends interlaced or non interlaced with the weft picks in the design. Alterations in the graft diameter and/shape can be achieved by gradually engaging and/or disengaging chosen warp ends with the weft picks in the design. When the fabric has been woven, the dropped yarns project from the fabric surface, and hence the projected areas of the dropped yarns are trimmed from the fabric. These contact or non-contact warp ends cannot alter the tubule size in a way that creates a seamless and gradual transition from one diameter to another and produce undesirable voids and gaps in the tubular wall. Obviously, the traditional weaving techniques are allowed to make tubular woven prostheses in single lengths or bifurcated structure, and the transition from one diameter to another occurs at a single point in the weave, creating a sudden change in the weaving pattern of the fabric in bifurcated or multi-diameter grafts, and have specific limitations as to the final shape of theproduct[31,32].

The other weaving technique to fabricate this graft is to utilize shrink characteristics of yarns in a controlled manner such that smaller diameter portions of graft are created through the shrinking of weft yarns[33]. On the one hand, the taper can be formed by means of this procedure; the non-uniform porosity and yarn spacing of the fabric structure can pose issues in surgery or the long-term durability of the prosthesis.

Also, the designer of these prostheses could get restricted by means of the shrink coefficients of the yarns to design geometries of adequate taper necessary for duplication of the human vessels.

Hence, an abrupt split in the existing methods creates gaps or voids in the weave at the splitting point, and a continuous flat-weaving method of gradually shaped tubular grafts has not been able to make diameter change in a gradual manner and a continuous process. On the basis of the ECF design, developed techniques manually weaving tubular prostheses by changing the height of cloth fell on the loom, which has smooth transitions from one diameter to another diameter and avoids gaps and voids in the tubular wall of the graft. In principle, this technique provides a solution against fluid leakage in transition areas[34]. However, the off-loom weft density of woven samples showed an observable difference from the value on loom[35]. Hence, it is required to primarily cut the relative movement inweaving and to rebuild the shedding geometric relationship.

On the basis of the ECF design and the basic shedding geometry, this study will rebuild the theoretical movement relationship among the front rest, and the cloth fell, the backrest on the loom, and also provides a computerized procedure on a customized rapier loom to automatically weaving the tapered tubular woven fabric with uniform porosity[36]. The ECF design has been adopted, and the geometrical relation between the cloth fell, the front rest height and the take-up length has been theoretically established in order to continuously weave the TCT woven graft with a uniform permeability along with the graft. The computerized weaving method has been evolved on a customized weaving machine having a trapezoid reed and has been based on this geometrical relationship.

It has been shown by the theoretical analysis that the upward and downward movement of the front rest in weaving results in the alteration of weft density. Hence, it has been proposed to control the take-up length on the loom that has been preliminarily assessed by weaving many kinds of TCT graft samples with the modified weaving parameter configuration. But, more implantation investigations are necessary to assess the structure uniformity, mechanical properties of the TCT graft prepared, and their relations.

IV. Conclusion

T-shaped 3D composites produced by the conventional method have been compared with innovative derivatives on and off the loom. In order to study the orientation of yarns and also study the samples from failure point after testing, a microscopic study has been conducted. An enhancement of about 47% in peel-off strength and about 70% in impact strength has been noted due to the combined variation of crossing and supporting layers. Modified T shapes offer a good substitute over T-shaped stiffener (used to avoid folding under loads) and in joints. On the basis of ECF design technique and the basic shed geometry, this study rebuilt the relative motion relationship among the front rest, and the cloth fell, the backrest, and the take-up length, and modified the weft density on the loom to achieve continuous weaving process of TCT fabric as well as the uniform porosity. And then, a computerized weaving procedure based on the rebuilt relationship was developed to automatically weave TCT fabric with different weaves on the customized shuttle loom. As a result, the uniform porosity of those samples validated the proposed weaving techniques.

References

[1] P.M. Wambua, &R. Anandjiwala, - A review of preforms for thecomposites industry. J.Ind.Tex.40(4)(2011) 310–333.

[2] X. Chen, X. Chen, L.W. Taylor, -An overview on fabricationof three- dimensional woven textile preforms for composites. Text.Res.J,81(9), 932–944,2011.

[3] M.S. Aly-Hassan, H. Hatta, &S. Wakayama, - Comparison of 2Dand 3D carbon / carbon composites with respect to damage and fractureresistance. Carbon, 41(5), 1069–1078,2003.

[4] Y.A. Bahei-el-din, & M.A. Zikry, - Impact-induced deformationfields in 2D and 3D woven composites. Composites Science andTechnology, 63(7)(2003) 923–942.

[5] R.A. Black, &T.V. How, - Attenuation of flow disturbances intapered arterial grafts. J.Biomech. Eng., 111(4)(1989) 303–310.

[6] K.E. Brown, A. Usman, M.R. Kibbe, M.D. Morasch, J.S. Matsumura,W.H. Pearce, P.D. Stein, - Effect of vessel taperingon the transition to turbulent flow: implications in the cardiovascularsystem. J.Biomech. Eng., 103(2) (1981) 116–120.

[7] S.B. Abdessalem, B. Durand, S. Akesbi, N. Chakfe, &J.G. Kretz, - Fluid-structure interaction in a free end textile vascularprosthesis. The Eur.Phy. J. Appl.Phy., 31(3) (2005) 211–216.

[8] C. Singh, C.S. Wong, &X.G. Wang, - Medical textiles as vascularimplants and their success to mimic natural arteries. J.Funct. Biomaterials, 6(3) (2015) 500–525.

[9] B. Thomas, &K.S. Sumam, - Blood flow in human arterial system-A review. 4th Intl. Conf. Emerging Trends inEngineering, Science and Technology (ICETEST), Vol. 24. ProcediaTechnology, Trichur, India: Elsevier Science BV. (2016) 339–346.

[10] R.A. Valencia, M.J. Garcıa, &J. Bustamantec, - A comparativecomputational study of blood flow pattern in exemplary textile vasculargrafts. J. Text. Inst., 108(6)(2017) 1–14.

[11] U. Krueger, A. Huhle, K. Krys, &H. Scholz, - Effect of taperedgrafts on hemodynamics and flow rate in dialysis access grafts. Artificial Organs, 28(7)(2004) 623–628.

[12] M. Sarmast, H.Niroomand-Oscuii, F. Ghalichi, &E. Samiei, - Evaluation of the hemodynamics in straight 6-mm and tapered 6-to 8-mm grafts as upper arm hemodialysis vascular access. Med. Bio. Eng.& Comp., 52(9) (2014) 797–811.

[13] K.E. Brown, A. Usman, M.R. Kibbe, M.D. Morasch, J.S. Matsumura,W.H. Pearce, M.K. Eskandari, - Carotid stentingusing tapered and nontapered stents: associated neurological complicationsand restenosis rates. Annals Vasc. Surg., 23(4)(2009) 439–445.

[14] W. Wang, W. Guo, X.P. Liu, X. Jia, H.P. Zhang, M.H. Zhang, &X. Du, - Study of ascending aortic elasticity in the Chinesepopulation with a high risk of aortic diseases. Int. J. Clinical and Exp. Med., 8(3)(2015) 3381–3390.

[15] K. Dransfield, C. Baillie, Y. Mai, K. Dransfield, C. Baillie, &Y. Mai, - Improving the delamination resistance of CFRP by stitching – areview. Comp. Sci. Tech., 50(3)(1994) 305–317.

[16] X. Wang, F.M.C. Ng, &J. Hu, J., - Shapeable stretch textiles via simpleweaves for seamless woven fashion. Text. Res. J., 79(18)(2009) 1715–1724.

[17] K. Bilisik, &N.B.N. Karaduman, - Fibre Architecturesfor composite applications. In S. Raul Fangueiro& S. Rana, Springer Science+Business Media(Ed.), Fibrous and textilematerials for compositeapplications, (2016) 75–134.

[18] B. Jang, M. Cholakara, B.P. Jang, &W.K. Shih, - Mechanicalproperties in multidimensional composites. Poly. Eng. Sci., 31(1)(1991) 40–46.

[19] N. Khokar, - 3D-weaving: Theory and practice. J.Tex. Inst., 92(2)(2001) 193–207.

[20] J.A. Soden, &B.J. Hill, - Conventional weaving of shaped preformsfor engineering composites, Comp. Part A: Appl. Sci. and Manufacturing, 29(7) (1998) 757–762.

[21] Y. Wang, &C. Soutis, - Fatigue behaviour of composite T-jointsin wind turbine blade applications. Appl. Comp. Mat.,24(2016) 1–15.

[22] P.B.Stickler, &M. Ramulu, - Investigation of mechanical behaviour of transverse stitched T-joints with PR520 resin in flexure andtension. Comp.Stru., 52(3–4)(2001) 307–314.

[23] D.U. Shah, - Developing plant fibre composites for structuralapplications by optimising composite parameters : A critical review.J. Mat. Sci., 48(18)(2013) 6083–6107.

[24] M. Umair, Y. Nawab,&K. Shaker, - Development andcharacterization of three- dimensional woven-shaped preformsand their associated composites. J. Reinforced Plastics and Comp., 34(24)(2015) 2018–2028.

[25] B. Sugun, &D. Sandeep, - Development of single-layer 3D “T”profile with fillet for composite “T” joints. J. Ind. Tex.,46(3) (2016) 887–900.

[26] K.K. Verma, D.N. Sandeep, B.S. Sugun, &S. Athimoolaganesh, - “Novel design of cocured composite T joints with integrally woven 3Dinserts”. Proc. 5th World Conf. 3D Fabrics andTheir Applications. Delhi., 16–17.2013.

[27] A. Mumtazi, K. Faizan, S. Salma, Z. Muhammad, N. Yasir, R. Rabia, A.M. Anam, M. Naveed&S.A. Aima, - Novelderivatives of 3D woven T-shaped composites with improved performance, J. Text. Inst. 4 (2018) 46-51.

[28] D.J.E. Lapointe, L.J. Vincent, &L.T. Wright, U.S. PatentNo.4771518-A. Washington, DC: U.S. Patent and Trademark Office.1988.

[29] S. Winner, &J. Coy, US Patent No. US9827086-B2.Washington, DC: U.S. Patent and Trademark Office.2016.

[30] S.C. Lee, J.W. Chung, J.H. Park, &S.G. Kang, Mechanicalproperties of newly developed ultra-thin bifurcated graft. Current Applied Physics, 12, S192–S197 (2012).

[31] T.V. How, -“Elastic deformation of a tapered vascular prosthesis.J.Mat. Sci.: Mat. Med., 2(2)(1991) 94–100.

[32] J.R. Hoffman, H.L. Tolsma, &L. Harmon, - U.S.PatentNo.3986828,. Washington, DC: U.S. Patent and Trademark Office.1976.

[33] R.E. Smith, &H. Ala, - U.S Patent No. 3853462. Washington,DC: U.S. Patent and Trademark Office.1974.

[34] X.Q. Dong, Y.L. Li, X. Ding, &L. Wang, - Research on themanufacture of tapered artificial vascular. Adv. Mat.Res., China: Tianjin Polytechnic Univercity, 331 (2011) 512–515.

[35] Y.Z. Wang, &Y.L. Li, - Research on auotomatic weaving of variablewidth fabric (Master’s thesis).Donghua University, Shanghai, China.2017.

[36] M. Fenye, L. Yuling, M. Yanxue&C. Xiaoying,- Development ofautomatic weaving technique of tapered circular tubular woven graft: a preliminary validation, J.Tex. Inst., 110:8 (2019) 1126-1131.