Medical textiles using Braiding Technology

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Abstract

To reduce the manufacturing cost of textile preform, braiding has become more and more important in the past few years. Braided materials, with light weight, high strength to weight ratio and good stiffness properties have come a long way in replacing the conventional materials like metal pipe, steel bars, shaft etc. for certain specific end user applications. Braided preform offers numerous advantages over other textile preform techniques such as, woven, non-woven and knitting. Nowadays, the use of braided preform has increased significantly in the manufacture of technical textiles. Traditional examples of the braided structures are electrical wires/cables, hoses, industrial belts and surgical sutures. New application areas for braiding include reinforcement structures of sporting goods like baseball bats, golf clubs, aerospace, automotive parts etc. Some of the medical textiles that are manufactured using braiding technology includes, sutures, biodegradable as well as non-biodegradable, prostatic stents, braided composite bone plate, bone setting device, braided pillar implants, artificial ligament or tendon, artificial cartilage, braided dental floss, surgical braided cable, braided biomedical tubing etc. Details pertaining to Meditech manufacture using braiding technology are discussed in this review.

Keywords: Textile perform, braided materials, knitting, technical textiles, sutures, braiding technology.

Introduction

Braiding is one of the four popular methods of fabric formation. A braid structure is formed by the diagonal intersection of yarns. In braided structure, there are no warp or weft yarns as in the case of woven structures. The process of braiding does not involve shedding or beat up mechanisms. The yarns concerned can be fed directly to the braiding machine from the creel. The feed packages can be either cones or cheeses. Traditional examples of the braided structures are electrical wires/cables, hoses, industrial belts and surgical sutures. New application areas for braiding include reinforcement structures of sporting goods like baseball bats, golf clubs, aerospace, automotive parts etc. Some of the medical textiles that are manufactured using braiding technology include:

(i) Sutures, biodegradable as well as non-biodegradable
(ii) Prostatic stents
(iii) Braided composite bone plate
(iv) Bone setting device
(v) Braided pillar implants
(vi) Artificial ligament or tendon
(vii) Artificial cartilage
(viii) Braided dental floss
(ix) Surgical braided cable and
(x) Braided biomedical tubing

Braids are suitable for surgical stitching thread or for strings supporting mechanically stabilizing ligaments or for setting bones for fractures.

‘Meditech’ manufacture using braiding technology

Sutures

Sutures are the most frequently used biomaterial for wound closure and tissue approximation (Chellamani and Veerasubramanian, 2010). They are used to close the cuts caused by injuries or to close the incision due to surgery and other medical procedures like wound approximation. They are commonly used on the skin, internal tissues, organs and blood vessels. There are two different kinds of sutures. One is absorbable sutures that will dissolve on their own. Another one is non-absorbable sutures that will be removed after certain period of time.

Multifilament/Braided suture

Multifilament yarns can be twisted together to form a braided sutures. To form a braided suture, in general, eight to sixteen monofilament yarns are to be used. Obviously, due to the manufacturing method, the braided sutures have rough surface which causes tissue drag to be high. A lubricant is applied on the surface of braided suture material to lower the tissue drag and allow better knotability. Braids are also flexible and easy to handle as compared to monofilament sutures. Polyesters, polyamides and silks are commonly used for manufacturing braided sutures. Braided silk is still the most flexible and supple material for sutures (Chellamani et al., 2012) and is particularly useful in cardiovascular surgery. Braided polyester is now used in many areas of surgery because it is strong, inert and compatible with body tissue.
Polyester suture material is particularly useful in cardiovascular surgery and as a component of medical devices. Figure 1 shows the braided suture for cardiovascular surgery.

**Prostatic stents**

The side view of a braided stent is shown in Fig. 2. The stent has segments of different strength and rigidity along its length. The device is said to be flexible enough for navigation through tortuous lumina but rigid enough to properly anchor the device and maintain patency at the site of treatment. The variance in diameter and/or radial strength or rigidity is achieved through the use of different numbers of filaments braided into the stent at different locations. Generally, where more rigidity or the same rigidity with a larger diameter, is desired, more filaments are added (Chellamani and Indra Doraisamy, 2008).

Figure 2 shows a non-bifurcated braided stent (100) comprising a narrow (smaller diameter) region (110) and a broader (larger diameter) (120). The broader region comprises a further batch of filaments braided into the filaments (ideally numbering 12) from the narrow region. The narrow region has greater flexibility than the broader region; the broader region exhibits greater radial strength than the narrow region. A transition region (130), which is formed on a mandrel of changing diameter, is located between the narrow and broader regions and comprises filaments that make up the narrow region. Figure 3a shows braided prostatic stent in human body and Fig. 3b shows braided preforms for prostatic stent.

**Braided composite bone plate**

In surgery, diaphyseal fractures are often treated by internally fixing the fractured bones together using bone plates. Currently, materials such as stainless-steel and chromium cobalt alloys are used in bone plates. The implantation time of bone plate in the body is in the range from 9 to 12 months. The bone plate is placed in position by bone screws, which are tightened to a certain torque. The elastic modulus of human bone, which depends on the sex and the age of a patient is in the range of 17–24 GPa. The bone modulus is much lower than the 110–220 GPa modulus of metal plates.
It is known that the human bone growth and deformation is affected by the surrounding loading environment. Due to the large stiffness difference between the bone and the metal bone plate, a big part of the load is borne by the bone plate rather than the underlying bone. As per reported results, at the fracture region, callus formation, ossification and bone union are retarded. The phenomenon is called the stress shielding or stress protection effect. This is one of the main drawbacks of using metallic bone plates. In order to avoid the problem, stiffness of the bone plate should match that of human bone. Polymer composites with their considerable flexibility in terms of mechanical properties are considered suitable for bone plate applications. The majority of composite bone plates, reported in literature are carbon/epoxy composites using short or unidirectional fibers. Recently, some studies are reported to be initiated towards fabrication of braided carbon/epoxy composite bone plates. Carbon fiber yarn (Diameter = 7 mm, 6000 Filaments: TOHO Rayon Co. Ltd.) was used as the reinforcement. Flat braided fabrics (Fig. 4) were preformed with 25 carbon fiber yarns using the braiding machine. Fabrics with three different braiding angles, i.e., 15, 20 and 25° were prepared in order to investigate the influence of braiding angle on the fracture behavior of composite bone plate. The R64/H3057 epoxy resin and polyamide hardener system by Chemicrete Company was selected as the matrix. Braided composites can be designed to display desired flexural properties. The braided composites exhibit desired fracture behaviors unlike that of the composites which have been reinforced with unidirectional fibres. The braided composites are highly suitable for bone plate application (Rama Krishnan, 2013).

**Bone setting device**

Two-dimensional braided composites are used as braided bone setting devices (Fig. 5). These are most often stiffness-critical applications and could benefit from lower stiffness open-mesh structured composites (Woo *et al.*, 1974; Akeson *et al.*, 1975; Bradley *et al.*, 1979). Studies have shown that the braid angle and thickness of a tubular cast can be tailored to produce stiffness’s similar to those of whole, unbroken bone.

**Artificial ligament or tendon**

Ligaments are bands of tough, elastic tissue that bind bones together at joints so that they can move. When a ligament is torn, it can either be repaired or replaced. Repair is the first choice, but often a torn ligament heals poorly and must be replaced. Most replacements come from connective tissues in the patient’s own body (such as a knee tendon). Rehabilitation and return to full strength can take one to two years. As anyone who participates in sports or other strenuous activities knows, the knee is very vulnerable to injury. When the knee is subjected to abrupt or progressive stress, one of its four ligaments is likely to tear. Repair or replacement of these ligaments is a major problem. To reduce rehabilitation time and provide greater strength, the W.L Gore Company developed an artificial ligament made out of Gorex. Gorex is a porous (full of small holes) update of Teflon (a tough material invented in 1969 best known for its use in waterproof materials). The 6 inch long Gorex ligament consists of about 1,000 fibers braided together for strength. The ligament is attached to the bones above and below the knee with stainless steel screws and soon becomes naturally anchored as the bone grows into and through the Gorex (Artificial ligament, 2013). Figure 6 shows braided artificial knee ligament or tendon.
**Mechanical behaviour of braided fibrous structures for artificial knee ligaments**

The use of braided fibrous materials as artificial grafts as they offer the possibility to mimic the structure as well as mechanical behaviour of artificial ligaments and the development of a special type of braided structure using polyamide 6.6 fibres for applications as artificial ligaments were attempted. The developed structures were circular braids, axially reinforced with a number of core braided structures. Tensile behaviour of these structures is characterized by the number of axial braids and the number of yarns used in the axial braids (Cruz and Juliana, 2012).

**Artificial cartilage**

To provide a biological material for an artificial cartilage which can be fixed by self-supporting without positional deviation to a biological (bone) tissue of a circumference without using auxiliary fixing tool or the like and to further provide the biological material for the artificial cartilage which is directly coupled to the biological (bone) tissue of the circumference in a relatively short period. The biological material for the artificial cartilage provides an initial self-supportability by projecting a distal end of a biodegradable absorbable fixing pin from at least one side surface of a core material made of a tissue structure in which organic fibers are made into braided structure or their composite structure (Shikinami Yasuo, 2003). The braiding technology is used to design three dimensional composite scaffold having similar mechanical properties to the natural one including compressive properties. The mechanical anisotropy and hydraulic permeability are also tailored to match the natural cartilage (Hyun-chul ahn et al., 2013).

**Braided dental floss**

A dental floss is formed as a yarn, including multifilament strands braided with each other in a multi-looped manner, so that forming knobs connecting the adjacent quasi-flat sections, while being stretched in a straight line, are subsequently disposed and twisted relatively to each other, whose cross section can be approximated to a rectangle-like figure having a width and a height greater than the width. The heights of two adjacent quasi-flat sections are disposed at a predetermined angle to each other. Due to particular braiding, quasi-flat cross-sections and the knob’s cross-section encompass different numbers of strand pieces, forming a multi-planar surface with bulges, thereby providing for a unique adhesive property increasing the floss cleaning powder, grabbing and removing plaque particles from the tooth surface more efficiently than the conventional ones. It’s exemplarily produced by means of adopted overlock machines, of polyester, colored, flavored, un-waxed, waxed, or impregnated with specific therapeutic agents (Zoya lavrova, 2011). Figure 7 shows multi-filament braided dental floss.

**Surgical braided cable**

Braided cable consists of several strands of braided wire laid vertically around a core (Fig. 8a). Cables are flexible, strong and resistant to crushing and distortion. Within the past few years, multi-stranded braided cables were introduced as a posterior fixation technique for spine surgery (Fig. 8b). Cables are stronger, more flexible and more fatigue resistant than monofilament wire.
Flexibility reduces the risk of neurologic injury during wire placement or removal, allows cables to conform to the shape of the bone surface, and allows an even distribution of tension along the bone-cable interface (Daniel et al., 2005).

**Braided biomedical tubing**

PEI offers high quality braided medical tubing that is available to meet the custom needs. Close tolerance, braid reinforced tubing is available in various configurations. Braiding can be done using round or flat, single or double ended wires as small as 0.001". Various materials can be used to make the braided reinforced tubing including stainless-steel, beryllium copper, and silver, as well as monofilament polymers. The braid can be wound with various picks per inch over many thermoplastic substrates such as nylons or polyurethanes.

The benefits of braided catheter shaft are its high torque-ability and kink resistance. By changing several factors during the braiding process, the characteristics of the tube can be altered to fit performance requirements. This braided catheter shaft tubing meets very high quality standards. After braiding is complete, a second extrusion is applied on top of the braided tube to encapsulate the braid and provide a smooth finish. Walls as thin as 0.007" can be achieved when a braid reinforced tube is required. The braided catheter shaft can be spooled or cut to lengths depending on your requirements (Precision extrusion, 2013). Figure 9 shows medical extruded tubing.

**Fig. 9. Medical extruded tubing (Precision extrusion, 2013).**

**Braided pillar implants**

Braided pillar implants are used in throat for reducing the snoring problems. These implants are shown in Fig. 10. Braided pillar implants with (a) Three tiny pillar braid inserts, (b) Pillar inserts are placed in the soft palate, (c) The pillar add structural support to the soft palate and (d) Braided pillar implant on the mouth (Braided pillar implants, 2006).

**Fig. 10a.** The pillar procedure uses three tiny inserts made from a soft, woven polyester material used in implantable medical products for more than 50 years.

**Fig. 10b.** The pillar inserts are placed in the soft palate using a specially designed delivery tool using only local anesthetic.

**Fig. 10c.** Once in place, the pillar adds structural support to the soft palate.

**Fig. 10d.** The pillar inserts cannot be seen or felt once in place and do not interfere with swallowing or speech.

Over time, the body’s natural fibrotic tissue response to the pillar inserts increases the stiffness and structural integrity of the soft plate.
Conclusion
From the review we can conclude that braided materials have the physical characteristics like light in weight, high strength to weight ratio and good stiffness. Braids are suitable for surgical stitching thread or for strings supporting mechanically stabilizing ligaments or for setting bones for fractures. Braided polyester is now used in many areas of surgery because it is strong, inert and compatible with body tissue. This is particularly useful in cardiovascular surgery and as a component of medical devices. The braided composites are highly suitable for bone plate application. The development of a special type of braided structure using polyamide 6,6 fibres is used for applications of artificial ligaments. The developed structures were circular braids, axially reinforced with a number of core braided structures. A dental floss is formed as a yarn, including multifilament strands braided with each other in a multi-looped manner. Multi-stranded braided cables were introduced as a posterior fixation technique for spine surgery. Braided pillar implants are used in throat for reducing the snoring problems. The benefits of braided catheter shaft are its high torque-ability and kink resistance.

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