Unit 1 Textile Technology
Lecture 1.4 Advances in braiding production

D 2.1 Training toolkit and e-book

May 2021 – Luminita Ciobanu (TUIASI)

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1.4 Advances in braiding production

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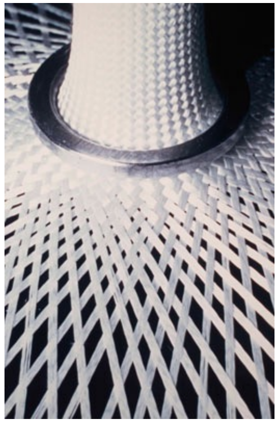
General characterization of braiding

Braiding is a textile process based on the intertwining of at least one set of yarns in bias directions. The intertwining positions the two sets of yarns at an angle between 10° and 80°.



The ratio with which the yarns are intertwined defines the structure of the braided fabrics: 1x1 (diamond), 2x2 (regular) and 3x3 (Hercules).

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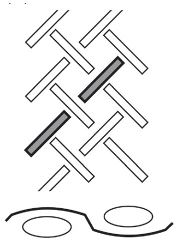
Structural braid notations

The "English" system consists of a few specified names for the popular structures – regular, basked and diamond. One more clear system from the engineering point of view describes structures in a form following "one over and under one," "one over and under two," etc.



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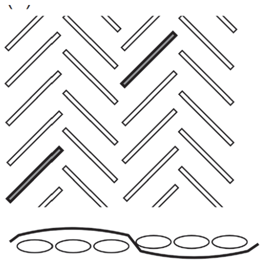
The "German" system is based on two numbers – the first describing the intersection type and the second the number of yarns per group. The system defines the floating length (Flechtigkeit) which describe how many yarns build the braid.
The pattern notation rule is:
X: X – Y
Over X groups: Under X groups – As a group of Y yarns



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Applications of braided structures

- clothing (outwear and lingerie); shoelaces;
- candle wicks;
- sleeves, cords, harnesses and ropes used for fishing and seafaring, offshore drilling, aeronautic industry and automotive;
- protection for electric cables;
- sport and leisure;
- composite reinforcement;
- medical textiles – scaffolds (tissue engineering), hard implants and non-implantable applications, such as elastic/nonelastic bandages, compression garments or orthopaedic devices.

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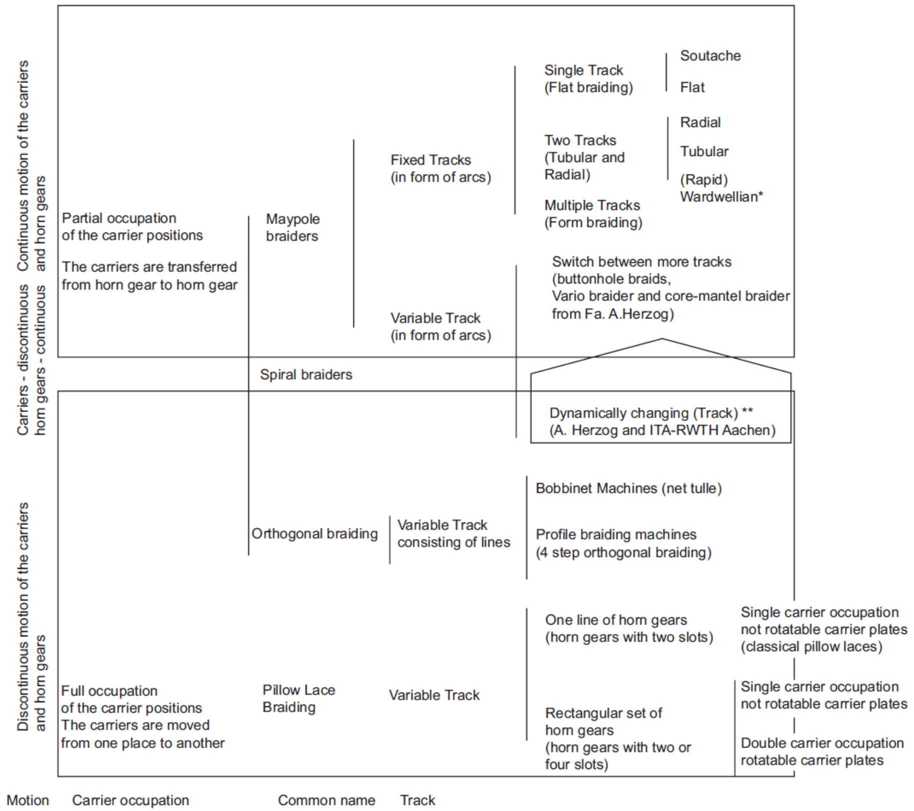
Machinery classification according to the type of the carrier position occupation and the tracks of the carriers



* Rapid or Wardwellian braiding do not use carrier transfer and horn gears.
** The machines with the dynamically changing track now (Year 2013) are still working on two steps (carrier motion, swich motion), but in case the electromechanical devices are able to switch fast enough, these machines will belong to the type of machines with continuous carrier and horn gear motion.

Machine classifications according to the motion type of the carriers and horn gears

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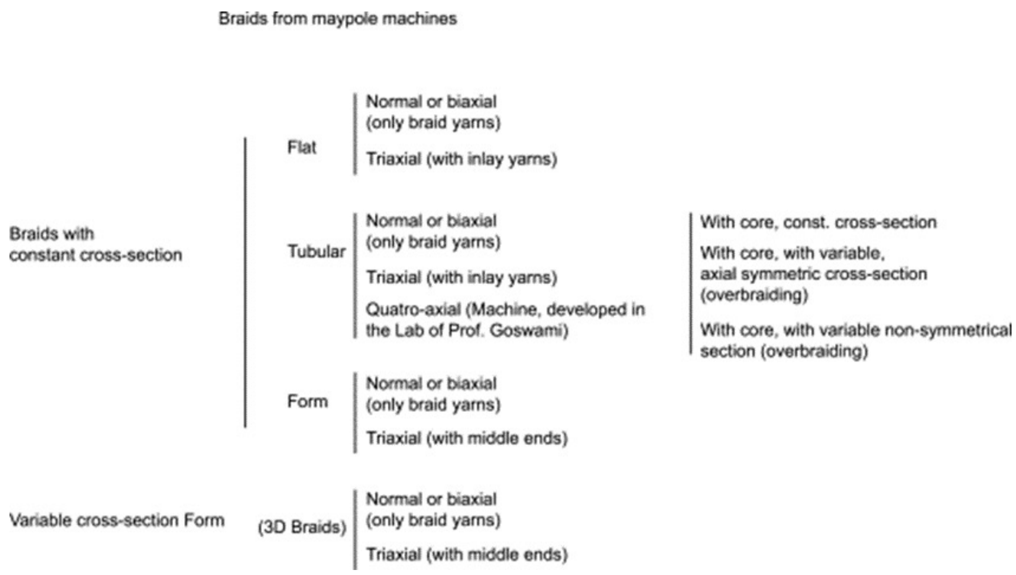
1. 2D braiding

2D braiding is the most common braiding process, in industrial and commercial terms. It includes different braiding principles, referring mainly to the way the horn gears are placed and carriers moved and the way the yarns interlace: **maypole braiding**, spiral braiding, lace braiding, bobbinet braiding.



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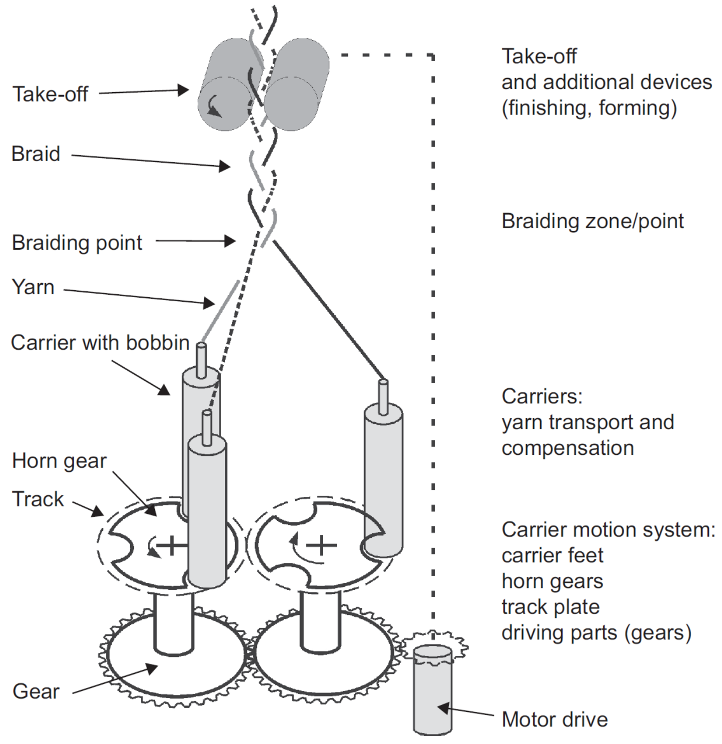

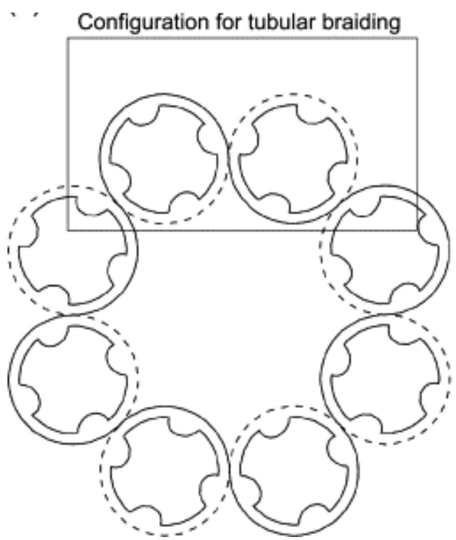

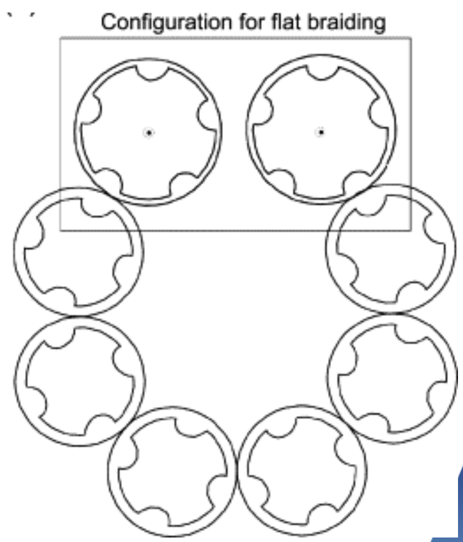

Basic principle of maypole braiding

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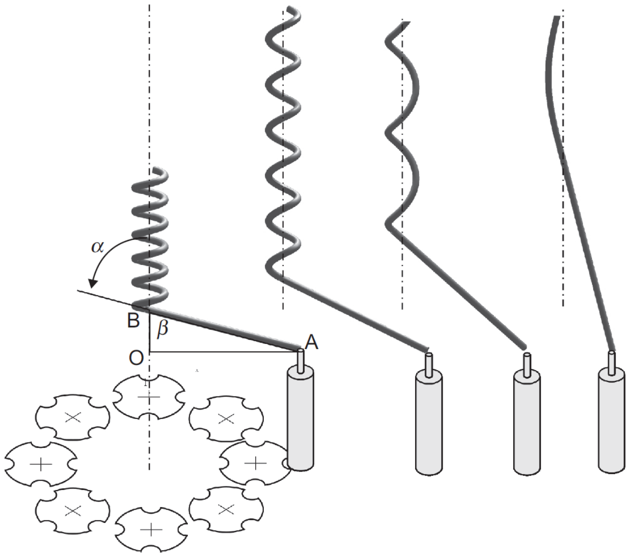
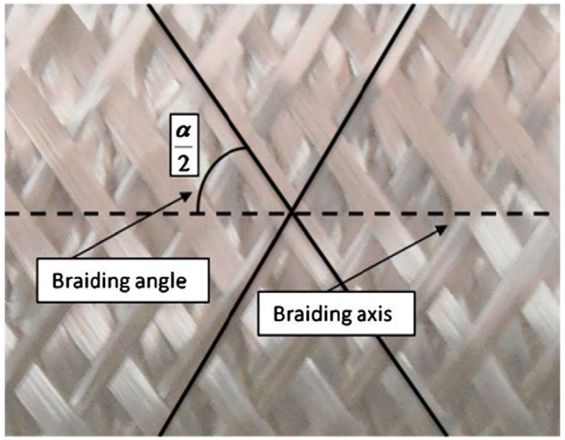
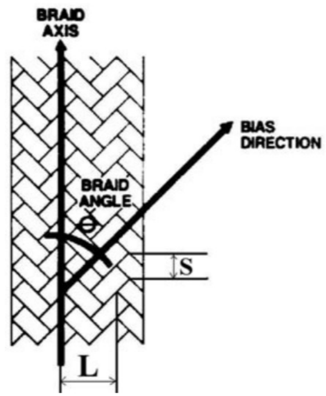


position of the natural braiding point depends on the take-off speed





position of the natural braiding point determines the braiding angle

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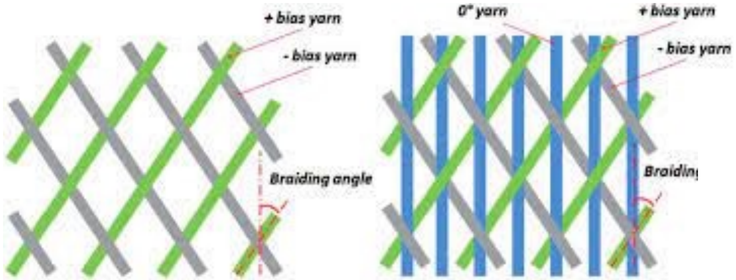
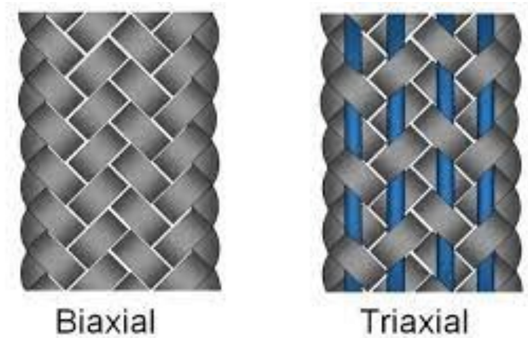
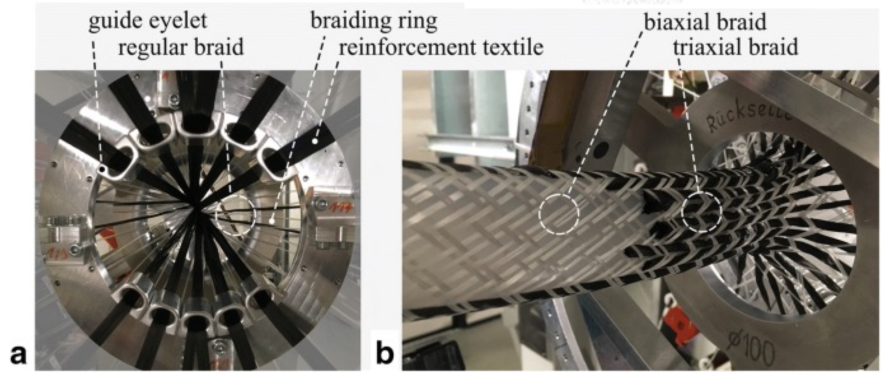
Triaxial 2D braids







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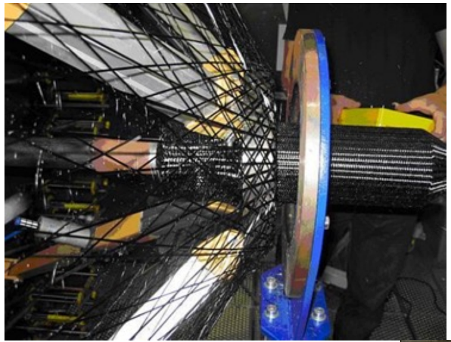

1.2. Overbraiding is achieved by using a shaped mandrel, placed on the braiding axis throughout the braiding process. The braided structure covers the mandrel in several layers, resulting in a preform that is generally used for composite reinforcement.

Certain machines have the mandrel positioned by a robotic arm, that can control its angle in relation to the braiding axis.

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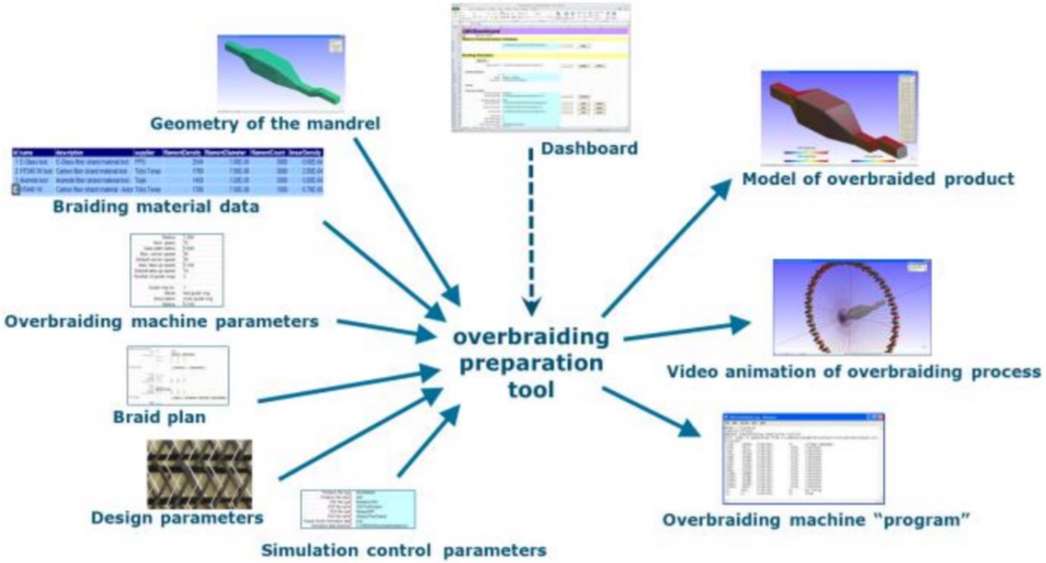
The main problem for overbraiding is to digitalize the braiding process, creating tools that will allow the programming of the braiding machine according to the geometry of the mandrel used, so that the resulting preform will have specific characteristics and will correspond to quality standards.



National Aerospace Laboratory NLR in the Netherlands, in collaboration with Eurocarbon BV and University of Twente developed an overbraiding preproduction support tool destined to replace the labour intensive, trial-and-error prototyping process.

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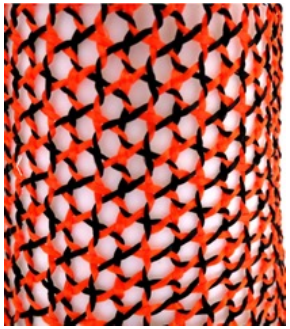
1.2. Lace braiding is a process similar to maypole braiding (circular or flat) where each horn gear is controlled individually, so that its movement direction can be reversed after each cycle to create independent strands.

TEF Braids (USA) develops complex lace braids based on proprietary technologies for Jacquard lace braiding. The tension distributive fabric structures are based on several patents: XhelX, IP (US 20140377488 A1) and ALX that allow extremely diverse structural possibilities.



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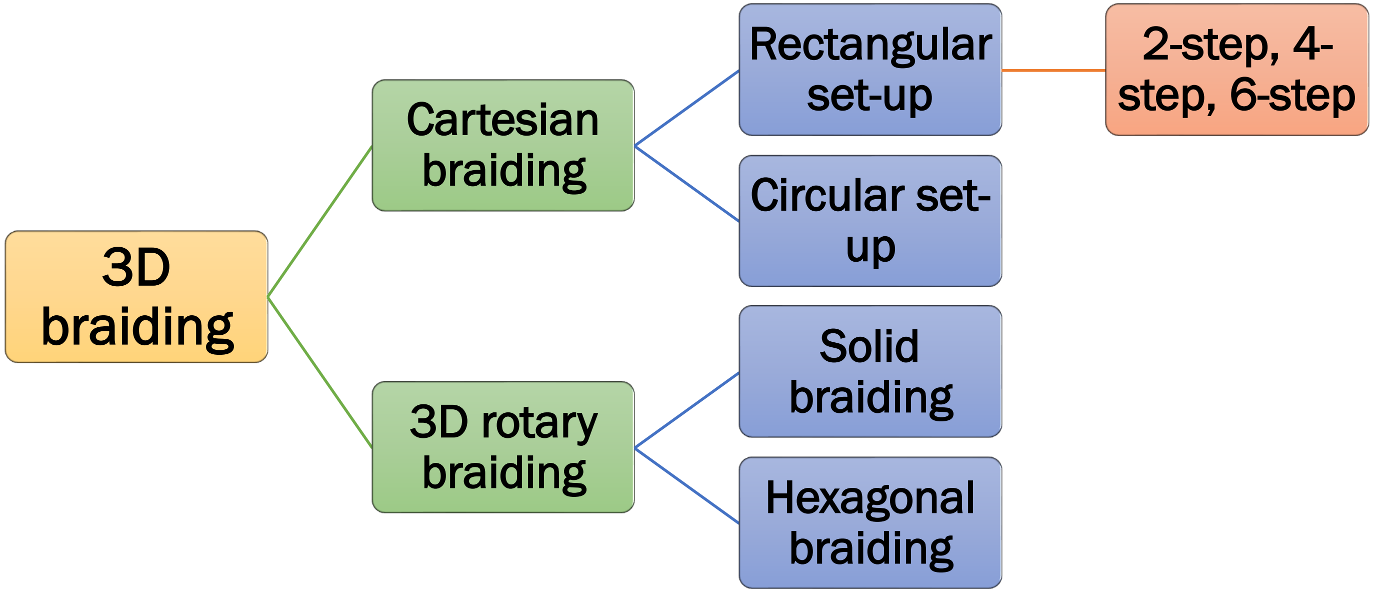
2. 3D braiding

3D braiding is characterised by the diversity of shapes, cross-sections and their through-thickness controlled mechanical behaviour based on yarn geometry.



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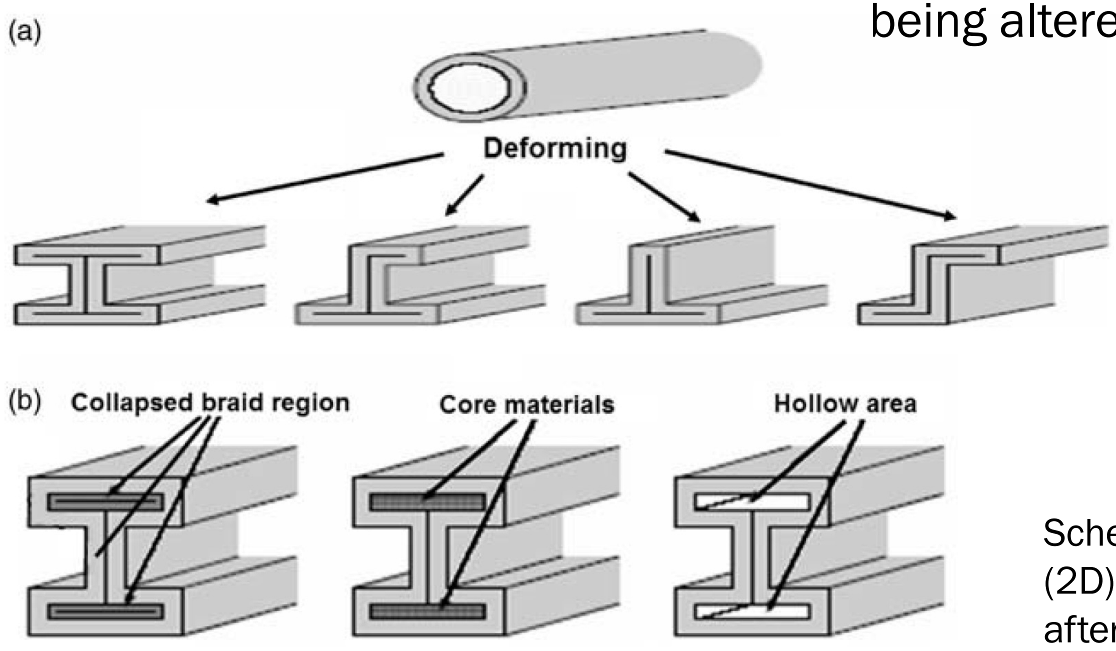
3D shapes can be obtain through 2D braiding, the resulting tubular braids being altered to correspond to 3D shapes



Schematical view of two-dimensional (2D) triaxial-braided tube before and after deformation making a sectional structural shape

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Number of yarn sets	Three-dimensional braiding 3D Braid Cartesian	 Polar	 3D axial braid Cartesian	 Polar	 Multiaxis 3D braid Cartesian	 Polar
1 or 2	Square Rectangular • Through-the-thickness (Out-of-plane at an angle) • 1 × 1 pattern 2 × 1 pattern 3 × 1 pattern 4 × 1 pattern	Tubular • Through-the-thickness (Out-of-plane at an angle) • 1 × 1 pattern 2 × 1 pattern 3 × 1 pattern 4 × 1 pattern			Rectangular • Through-the-thickness (Out-of-plane at an angle)	Tubular • Through-the-thickness (Out-of-plane at an angle)
3			Triaxial fabric • Braid yarn in surface (In-plane) Rectangular • Through-the-thickness (Out-of-plane at an angle) • 1 × 1pattern 2 × 1 pattern 3 × 1 pattern 4 × 1 pattern	Triaxial fabric • Braid yarn in surface (In-plane) Tubular • Through-the-thickness (Out-of-plane at an angle) • 1 × 1 pattern 2 × 1 pattern 3 × 1 pattern 4 × 1 pattern	Rectangular • Through-the-thickness (Out-of-plane at an angle)	Tubular • Through-the-thickness (Out-of-plane at an angle)
4					Rectangular • Through-the-thickness (Out-of-plane at an angle)	Tubular • Through-the-thickness (Out-of-plane at an angle)
5 or 6					Rectangular • Through-the-thickness (Out-of-plane at an angle)	Tubular • Through-the-thickness (Out-of-plane at an angle)

Classification of 3D braids

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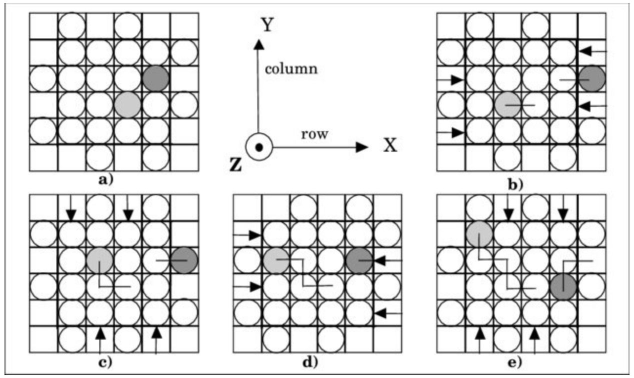
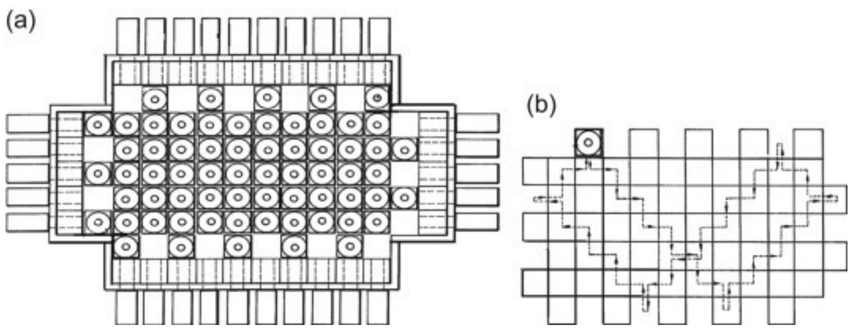
2.1. Cartesian 3D braiding

For **cartesian 3D braiding** (track-and-column braiding) carriers are moved in groups, by tracks, respectively columns. In the 4-step process tracks and then columns of carriers are successively displaced in opposite directions in four stages.





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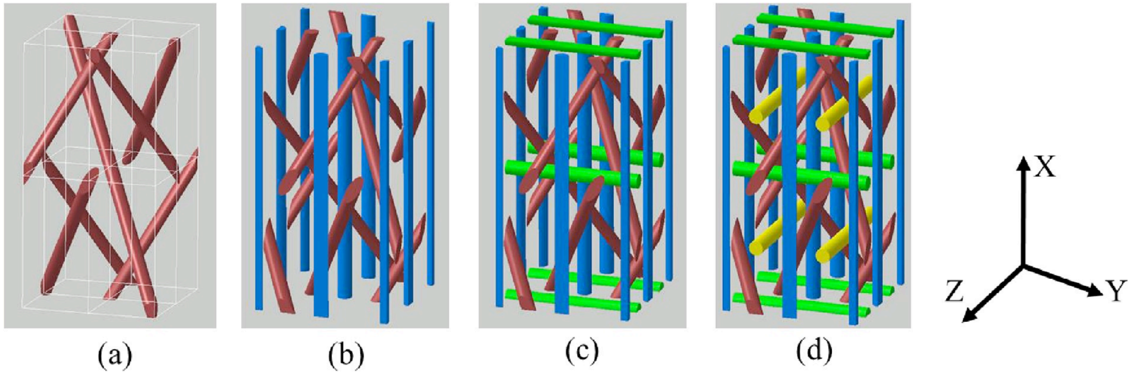

Geometry of reinforced cartesian braided structures - a) 3D 4d (only braiders), b) 3D5d (+warp yarns), c) 3D6d (+warp and filling yarns) and d) 3D7d (+warp yarns, filling yarns and Z-axis yarns)

6-step braiding process was developed based on the 4-step one to increase the fabric strength on all three directions by introducing yarns parallel to the axis (warp yarns, filling yarns and Z-axis yarns).

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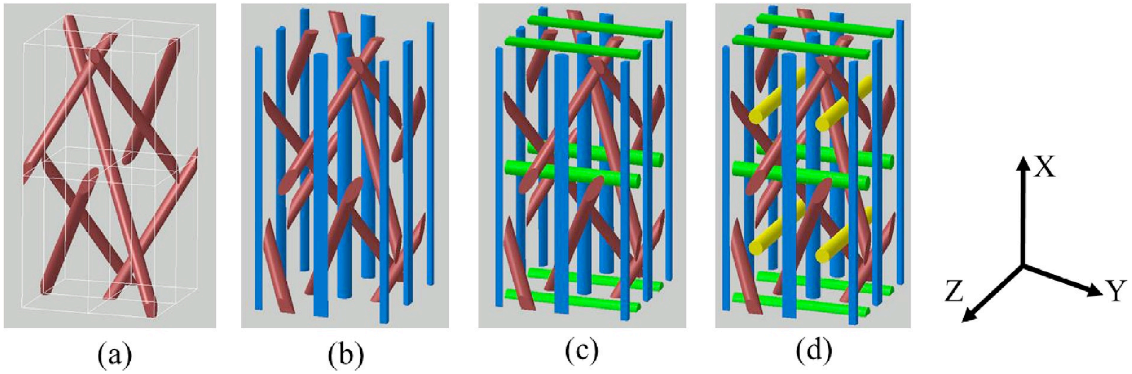

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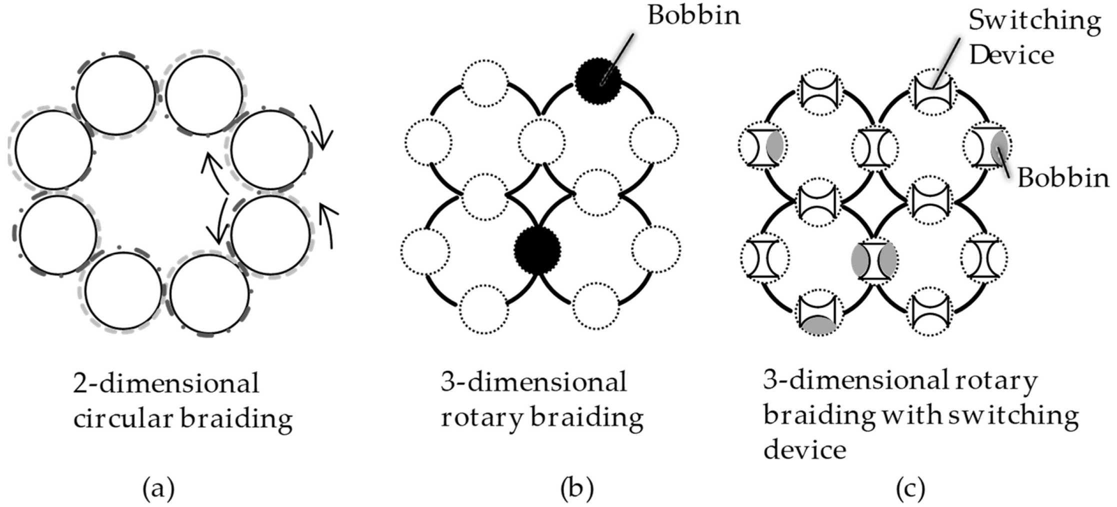
2.2. 3D rotary braiding

3D rotary braiding process is an adaptation of maypole and lace braiding with a different arrangement of horn gears (rectangular) and, most important, modified mechanism for track-switching of the carriers between horn gears so that the path of the carrier is controlled independently.



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1.4 Advances in braiding production

a) Solid (form) braiding

Adapted maypole machines can be used to produce solid braids with square cross-section, known as gasket / 2.5D / packing / form braids. The carriers have a square arrangement according to the number of tracks to be formed by the braiders: 2-track system (2D braids, where D stands for diagonal); 3-track system (3D braids) and 4-track system (4D braids).

Graphite packing is a highly resistant sealant used in systems with valves, faucets, and stuffing boxes, as well as other machines with watertight mechanical parts. It can be applied either to static valve stems or to moving joints. Graphite packing offers high chemical resistance, great lubricity, and excellent thermal conductivity.

PTFE fluocarbon filament tape.
Use - Glass and glass-lined pipe flanges, Glass and glass-lined pipe vessels, Stainless steel reactors, Ceramic-lined tanks and vessels. Recommended for the most severe services. All oxidizers and corrosives with one exception: molten alkali metals. Temperature up to 260°C; pH range 0 - 14.

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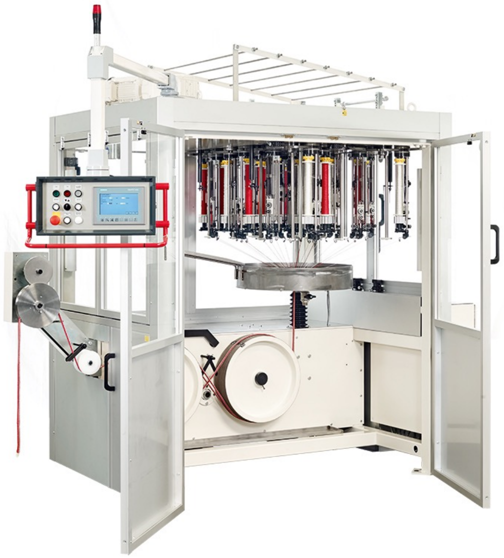
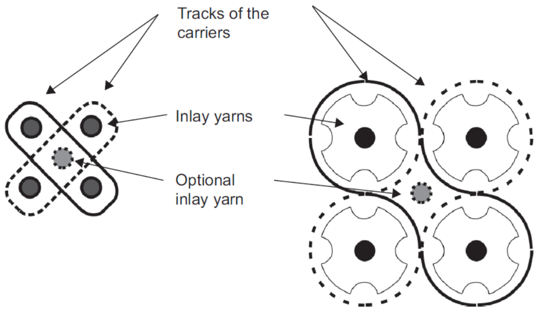
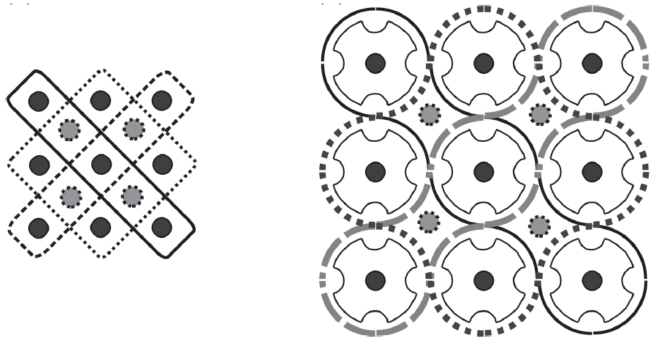
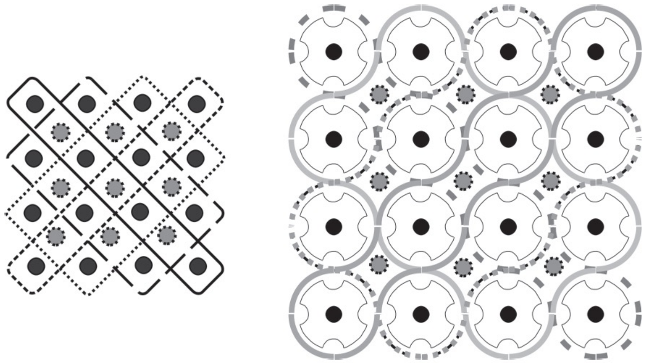




Two-track braiding of square braids



Three-track braiding of square braids



Four-track braiding of square braids

The packing braiding machine (Herzog) can be adapted for 2, 3 or 4-track. It presents sleeve type carriers, according to the pitch size for bobbin sizes of 72 x 285 mm up to 135 x 300 mm.

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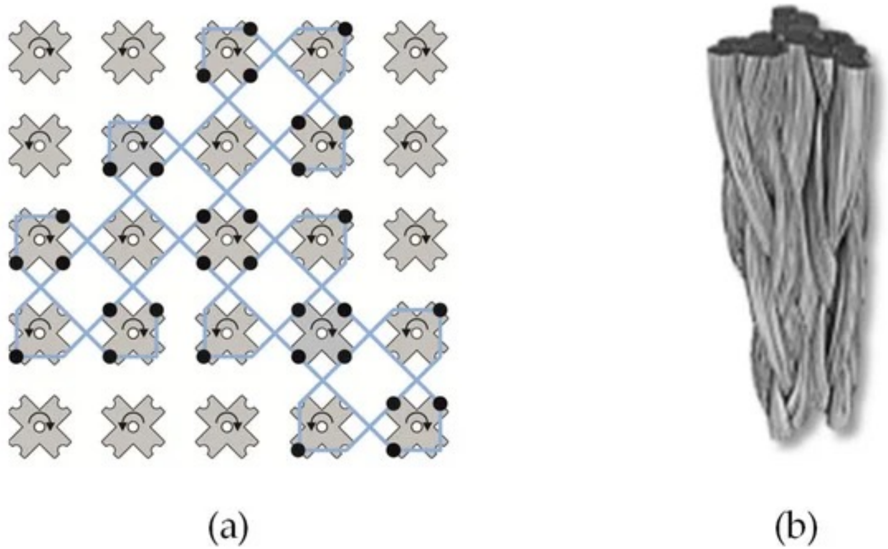

(a) Programming of bobbin configuration; (b) 3D braided textile preform in a T-profile-like geometry.

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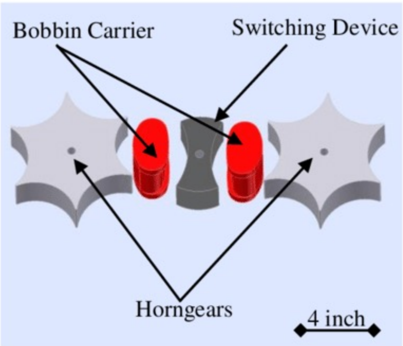
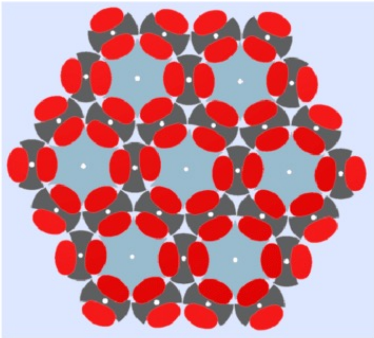
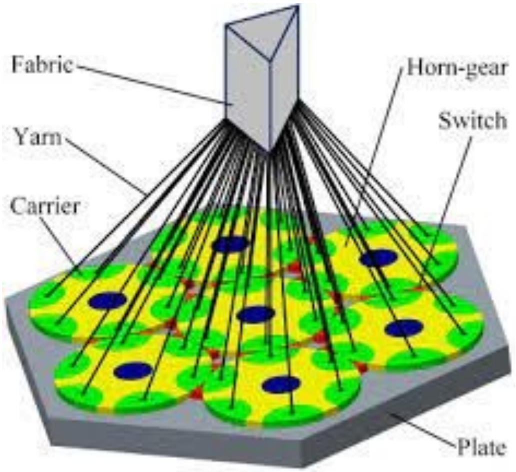
b) Hexagonal braiding

Hexagonal 3D braiding is based on a different approach to horn gear 3D braiding by arranging the horn gears in a hexagonal shape. This position ensures the carriers are displaced with smaller increments, as they are closely to each other, thus changing the angle between braided yarns.







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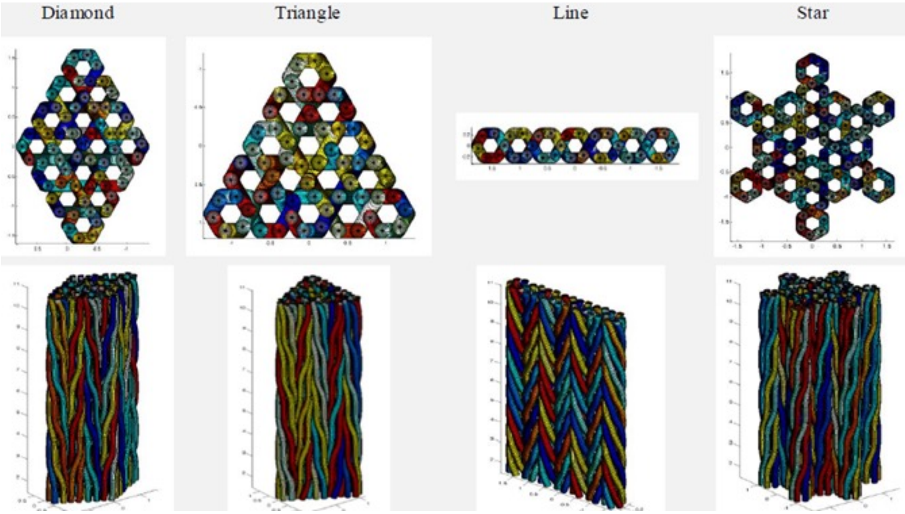
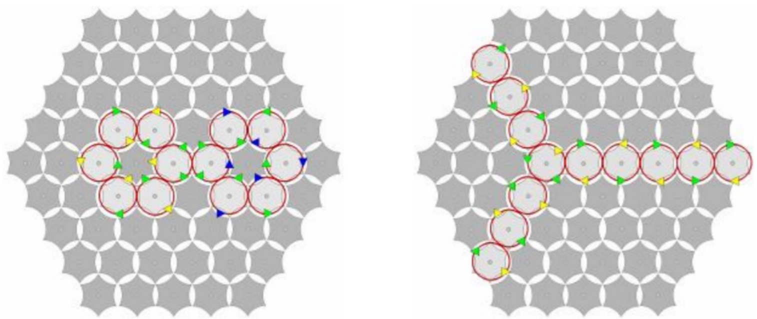


Simulations of possible hexagonal braided structures and shapes



3D-braiding patterns: Double - tubular (left) and Y-beam (right).

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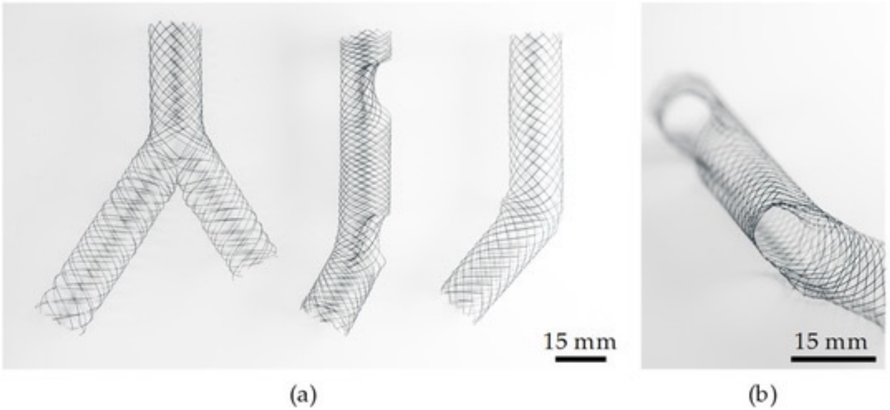
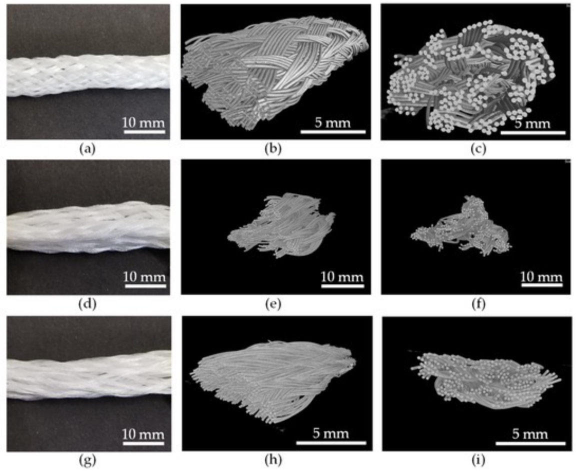
1.4 Advances in braiding production

Applications of hexagonal braiding in medicine



Complex **nitinol stent structures** manufactured by 3D hexagonal braiding: (a) bifurcation stent, stent with patient individualized cut-outs, and J-stent with a diameter of 15 mm; (b) close-up of the cut-outs created by changing the braiding pattern from a round to a flat braid.
https://www.mdpi.com/2673-7248/1/2/9/htm



Different **3D braided scaffold** designs manufactured on the 3D hexagonal braiding machine: (a–c) “multilayer braid”, (d–f) “three-tube braid”, (g–i) “six-tube braid”; (a,d,g) photographs, (b,c,e,f,h,i) micro-computed tomography (μ-CT) scans.

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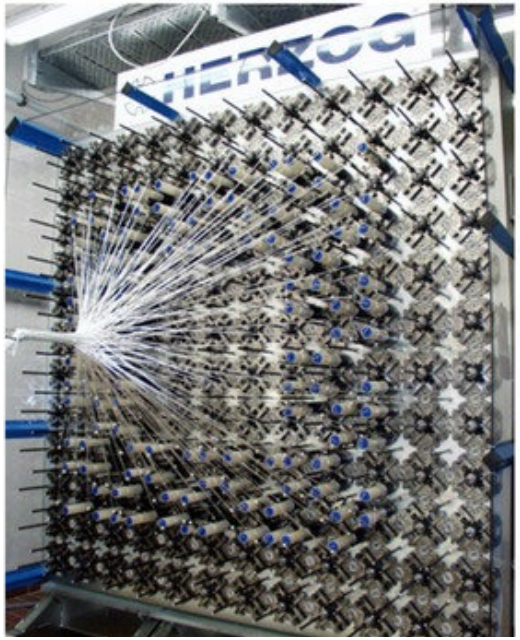
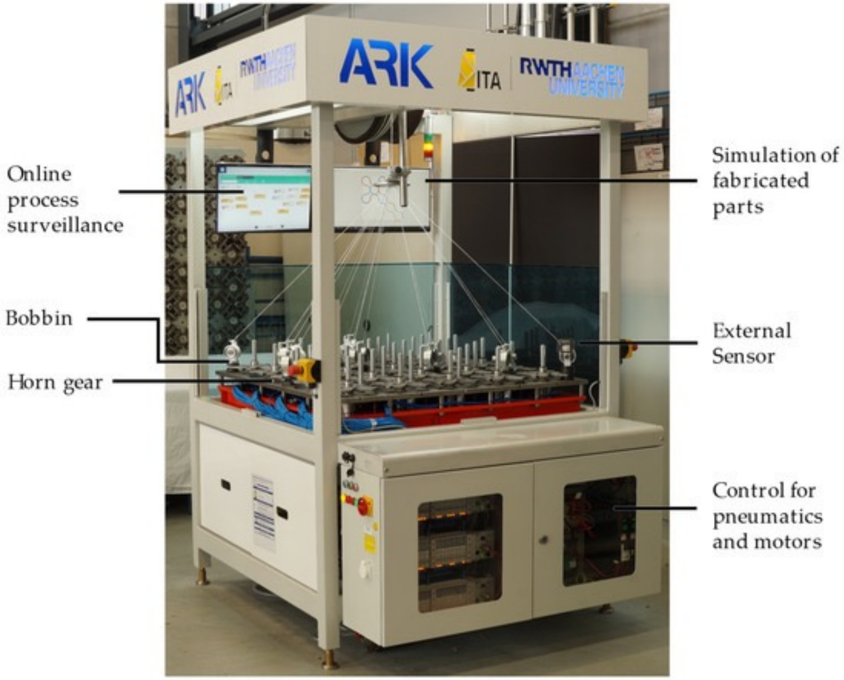
1.4 Advances in braiding production

Rotary braiding Herzog



9-module Herzog 3D rotary braiding machine



Retrofitted rotary 3D braiding machine at Institut für Textiltechnik (ITA)

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1.4 Advances in braiding production

Rotary braiding 3TEX

The US company 3TEX designed a rotary braiding machine that presented an original track-switching mechanism where carriers are transferred between horn gears in pairs using a rotary gripping fork (called RGF). The horn gears are arranged in elementary cells that are assembled to form modules and these modules can be put together to create different configurations in terms of geometry and size. This composed architecture of the machine's arrangement and the CAD system developed to define the activation pattern of the RGFs according to shape allow for an enhanced production flexibility in terms of fabric geometry and cross-section.

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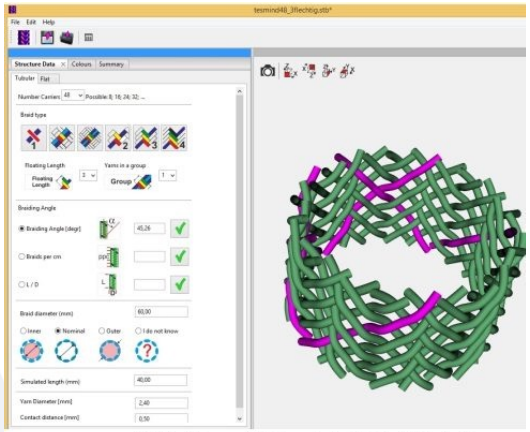
3. CAD systems for modelling the braiding process

3.1. TexMind software

TexMind Braider is an intuitive CAD-Software for colour and structural design of standard tubular and flat braids. The user defines the number of the yarns, the braiding type and the dimension of the braid. It has a Standard version and a Multifilament version.



(C) TexMind UG 2015
www.texmind.com

Yarn Data			
Yarn Linear Density	tex	22.98	
Yarn Type	-Name-	PES	
Yarn Density	g/cm^3	1.3	
Yarn Diameter	mm	0.15	0.00591
Number Yarns(plays) at one bobbin	---	6	
Effective Yarn Fineness (per Carrier	tex	137.88	
Bobbin Data			
Bobbin Min Diameter	cm	1.5	
Bobbin Max Diameter	cm	2.5	
Bobbin Width	cm	100	
Bobbin Volume	cm^3	314.15	
Wound Package Density	g/cm^3	0.8	
Bobbin Masse	g	251.32	
Bobbin Length	km	1.82	
Winding Machine Data			
Winding Velocity	m/min	1	
Total Winding Time per Bobbin	min	1822.74	
Number Winding Heads	---	1	
Total Winding Time for all carriers	min	43745.87	
Braid Data			
Rope Length (without knots)	km	1.82	
Rope Masse per meter	g	3.31	
Braiding Machine Data			
Meters Rope per Hour	m	200.40	
Hours to next bobbin Change	hour	9.10	
Braid coverage			
Angle ANSI/SCTE 51 2002	Deg		46.11
F			0.96
Cover Factor ANSI/SCTE 51 2002	%		99.86

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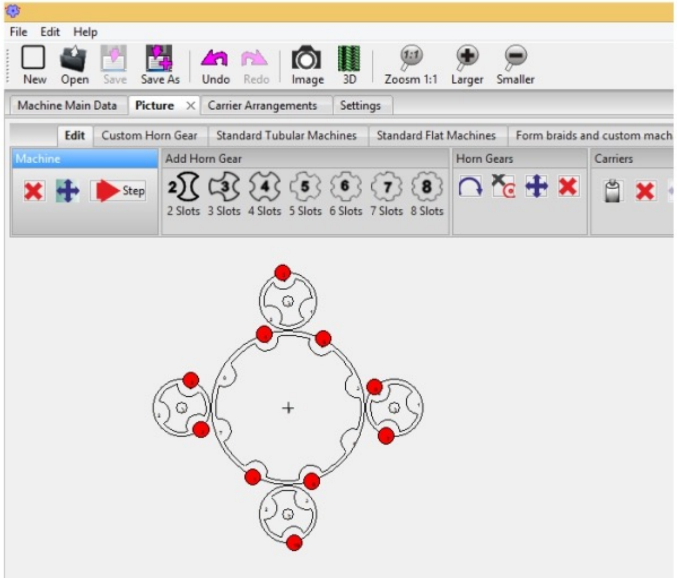
1.4 Advances in braiding production

Texmind Braiding Machine Configurator simulates the braiding process using horn gears with any number of slots, according to carrier placement. The software creates an animation of the carrier motion and checks for possible collision. It also simulates the idealized 3D structure of the braid.

- Horn gears with 2,3,4,5,6,7,8,....
- Any number of slots
- Carrier placement
- Show animation of the carrier motion
- Idealized 3D structure of the braid
- Collision check



- Export the machine drawing as WMF (windows image format) and SVG (Corel Draw, Web)
- Export the braid as 3D geometry or jpg
- Export the machine emulation as GIF animation

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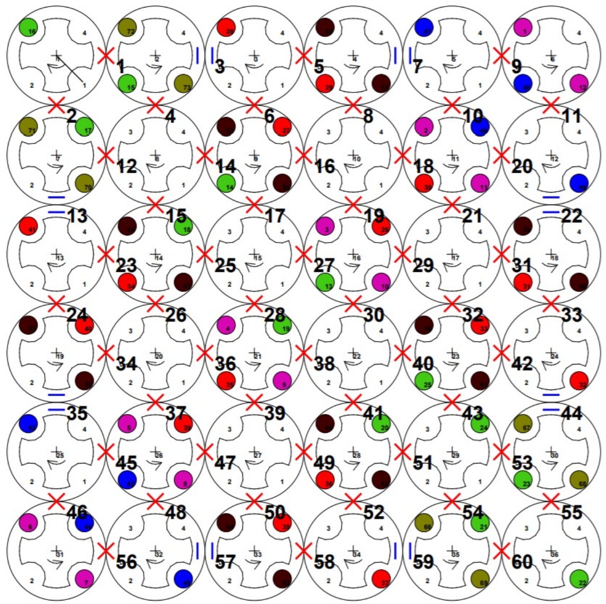
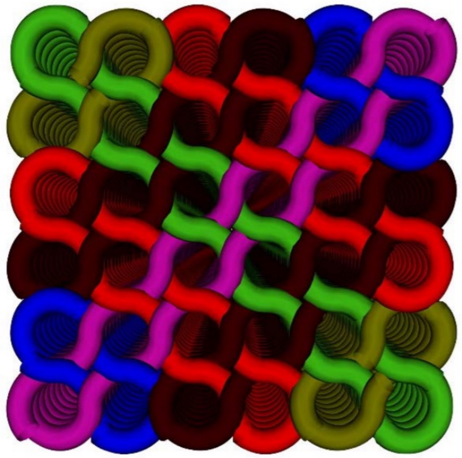
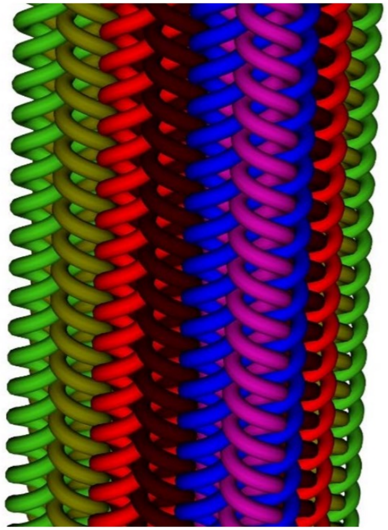
1.4 Advances in braiding production

Braiding machine configuration for production of solid braided structure with not full connected 10 tracks







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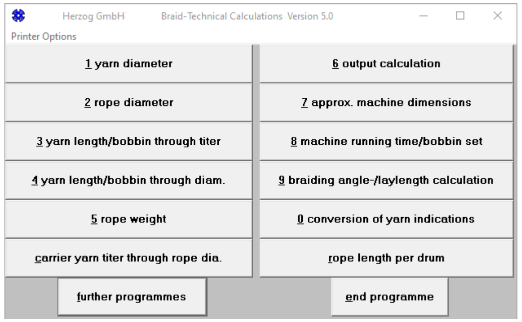
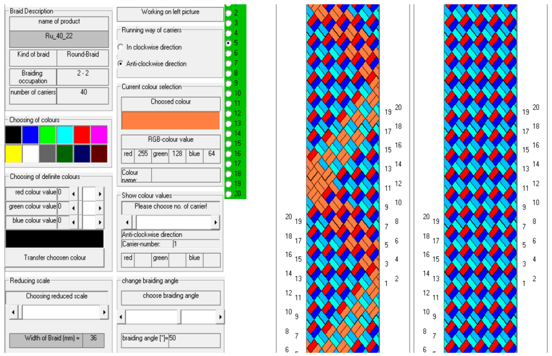
1.4 Advances in braiding production

3.2. Herzog software

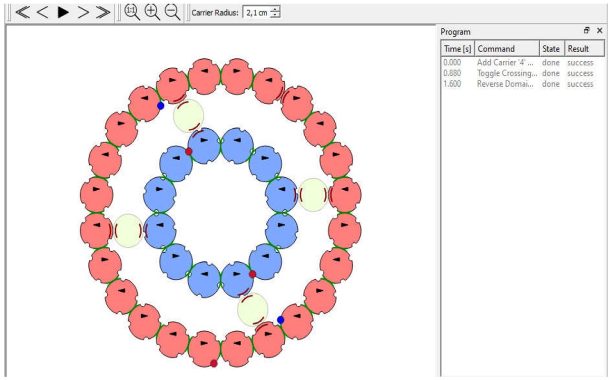
Computer Aided Braiding (CAB) by August Herzog Textilmaschinenfabric GmbH for their braiding machinery



1. CAB Calculations – for braid design and machine operation



2. CAB Design – simulation of braid structures, including colour patterns



3. CAB Soft – simulation of carrier paths on advanced braiding machines

4. MDA – Machine data acquisition

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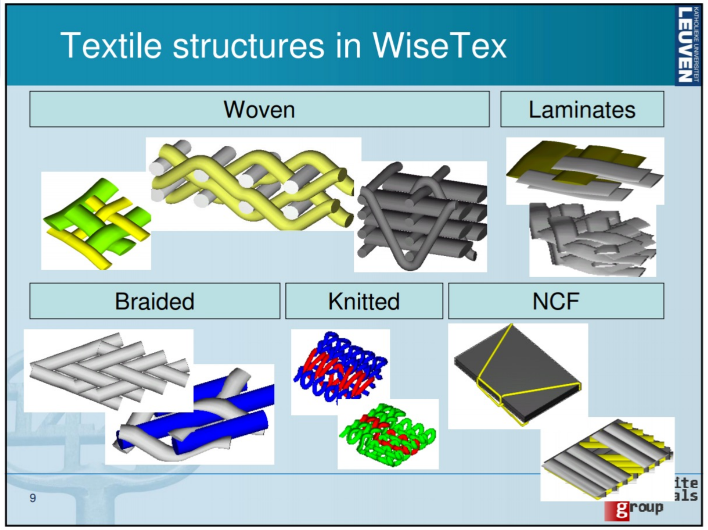
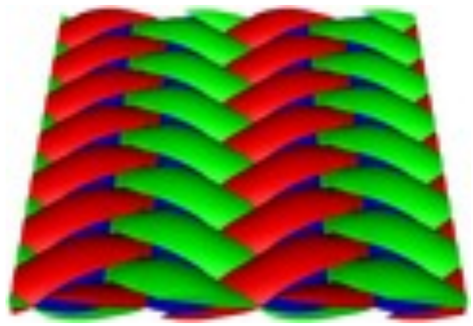
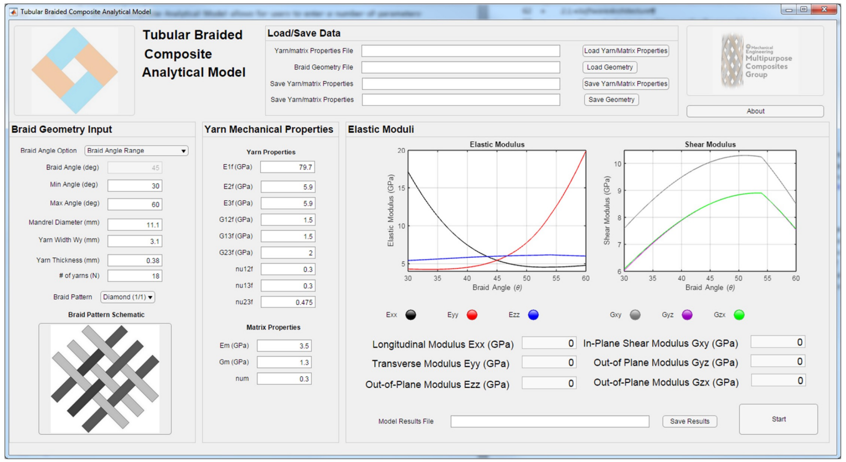
1.4 Advances in braiding production



WiseTex 3.0 design of textile reinforced composites (KU Leuven, Belgium)

TexGen - open source software developed for modelling the geometry of textile structures. (University of Nottingham)





Braid CAM - design and manufacture of braided composites

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The partners

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