COST Action TU1207

Next Generation Design Guidelines for Composites in Construction

Design of filament wound glass reinforced plastic (GRP) pipes for construction

Action Meeting
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Kaiserslautern, Germany

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- a brief description of composites and the filament winding process

✓ will be describe components of composite materials - used resin systems and fibers

✓ basic definitions and general information about filament winding process

- design of the experiments

- produced filament wound tubes

- application

Development

requirement of materials that cannot be met by the conventional monolithic materials

New composites

heterogeneous nature

properties of composites = F (constituent materials, their distribution, and the interaction among them)

New applications

an unusual combination of material properties can be obtained

is accelerating

Continuous fiber reinforced composites

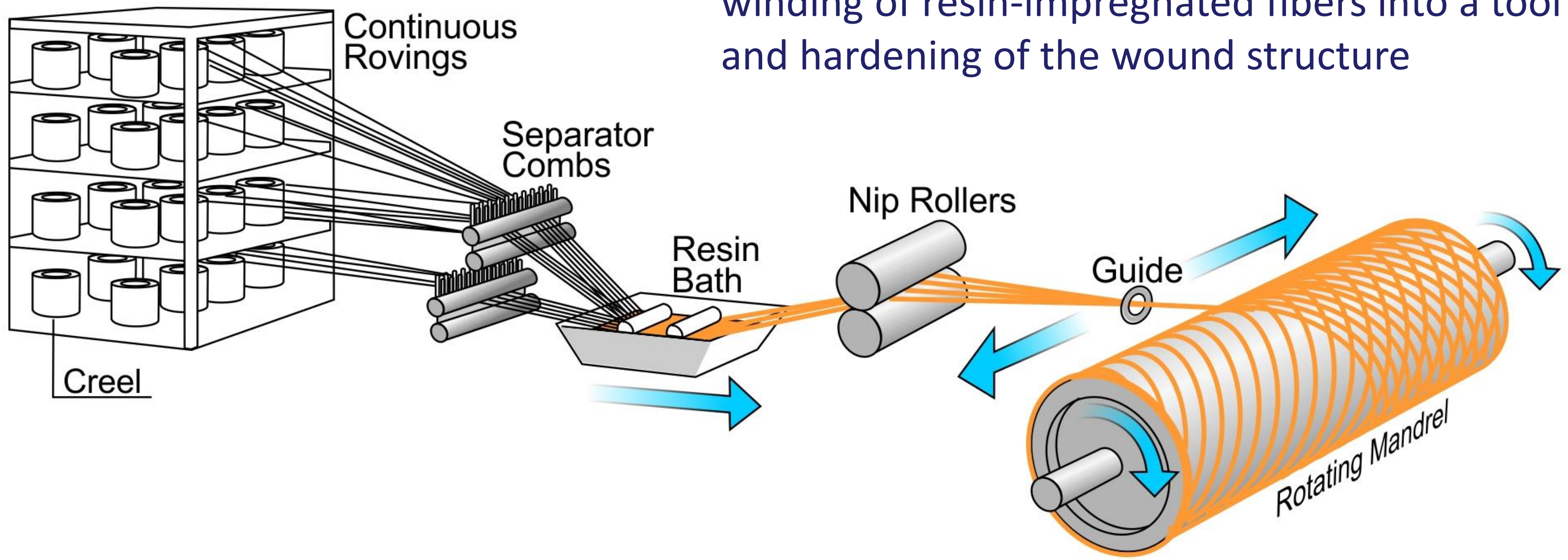
- produced by long fibers with high aspect ratio
- a fibrous reinforcement - length much greater than its cross-sectional dimension
- much attention due to their better mechanical properties.
- a wide range of application area due to their anisotropic nature
- the direction dependence of their properties results in much better design flexibility that cannot be obtained by monolithic materials or particle reinforced composites.

Filament winding technique - one of the most common production technique

Filament Winding Technique

- a reinforcing agent in the form of continuous fibers (glass, carbon, aramide, etc.)
- an impregnation agent in the form of liquid resin (polyester, epoxy, etc.)

winding of resin-impregnated fibers into a tool and hardening of the wound structure



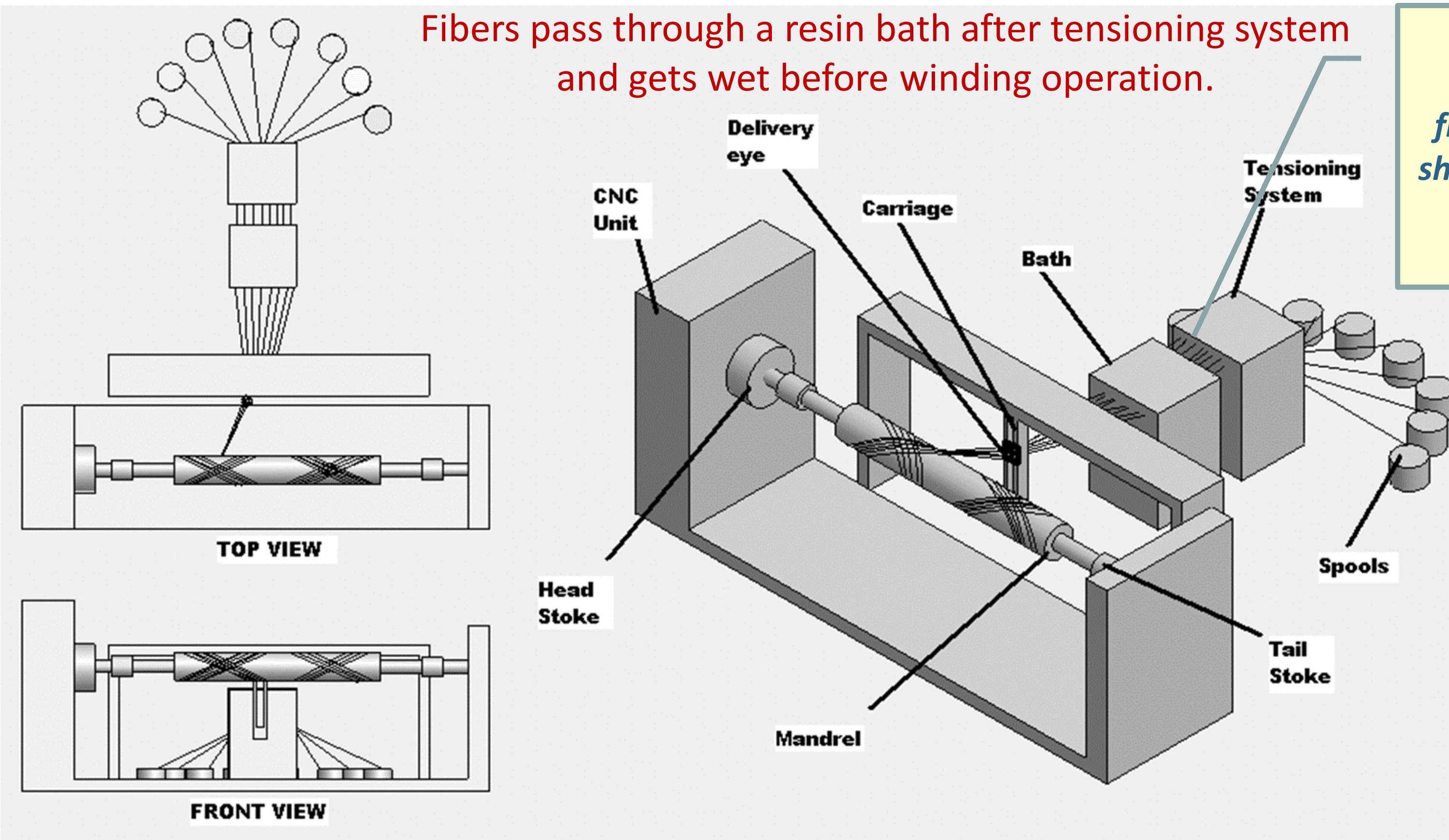
this technology enables the fiber to be placed into the direction of the load that may be expected during exploitation of construction elements !

Filament Winding Technique

- the mechanical properties of fibers in the longitudinal direction can be maximally exploited
- for creating **new materials with distinct anisotropy** according to the direction in which the fiber is placed
- different directions result in a material with different mechanical properties
- produced composite materials have the highest percent of fibers of all composite materials and small density
- for loaded elements of construction, which also need to have small mass

Filament Winding Technique

Fibers pass through a resin bath after tensioning system and gets wet before winding operation.



tension changes the friction force between fiber and the mandrel, it should be kept at a certain value during winding operation

resin content – excessive resin, due to a low tension, can result in decreased mechanical properties

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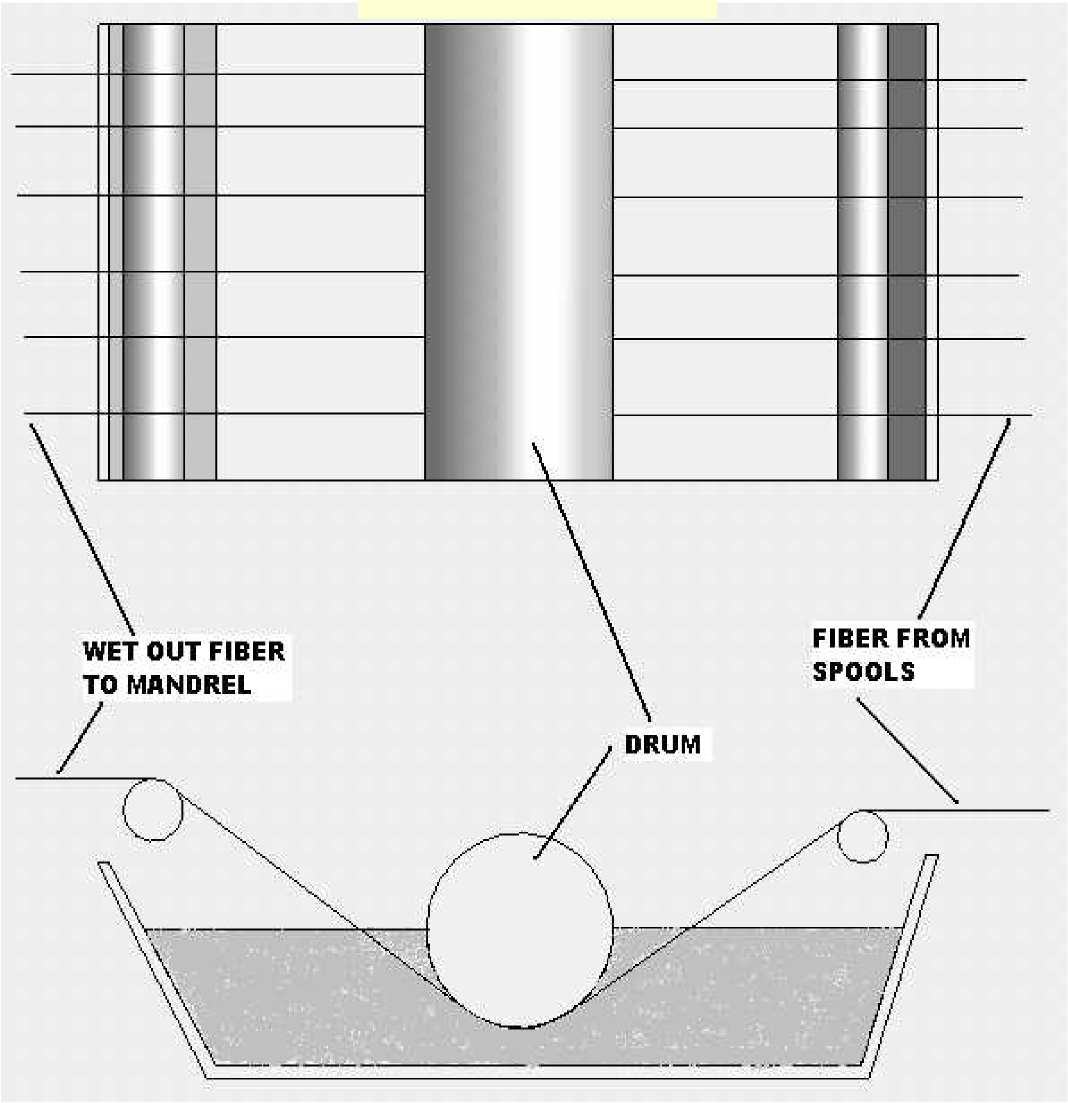
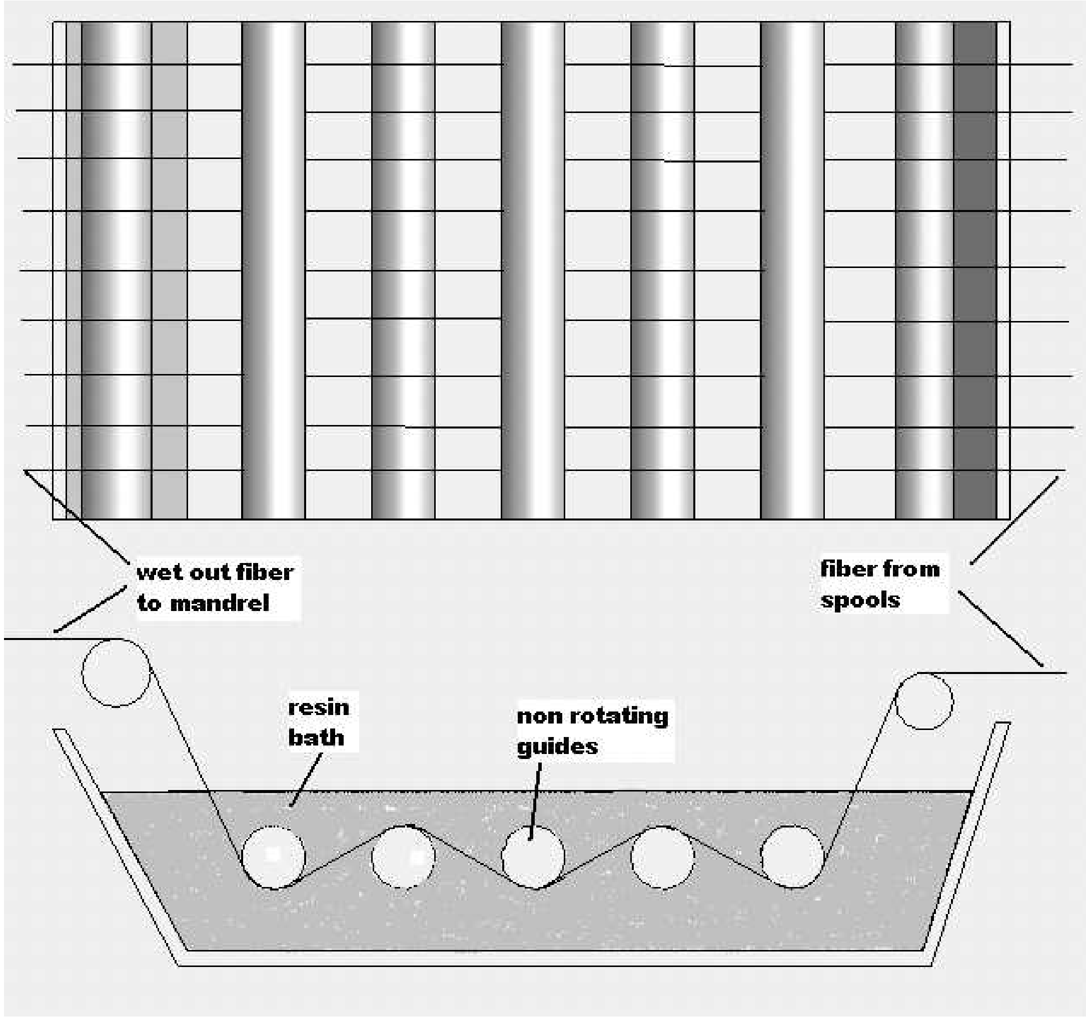
Wetting can be done by two commonly used bathing type:

Drum Bath



- less fiber damages
- can be heated for a better wetting action
- lowering resin viscosity, reducing fiber speed, increasing fiber path on the drum - for better wetting action
- especially important when using carbon fibers

Dip Bath

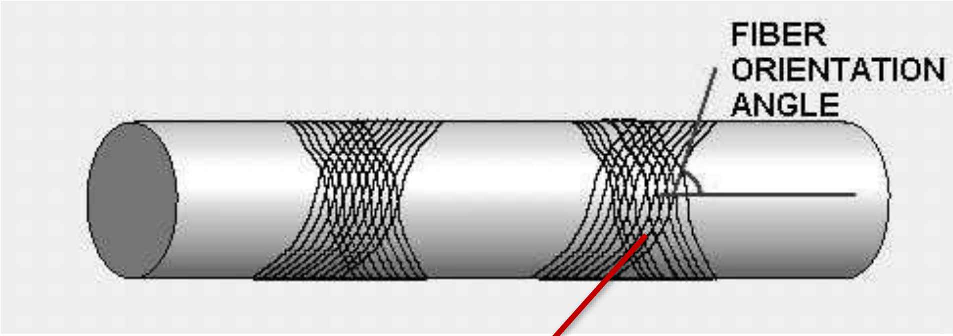


- better wetting
- resin can be heated
- non-rotating surfaces are used for guidance
- non-rotating surfaces provide good wetting
- with aramid or glass fibers

If fibers are not wetted in a desired way, air bubbles can be trapped between them and can cause voids in the composite part !!! - decreased mechanical properties

Each layer of reinforcement can vary in

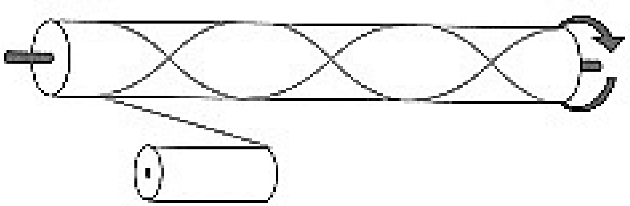
1. **winding tension,**
2. **winding angle,**
3. **velocity of winding,**
4. **resin content.**



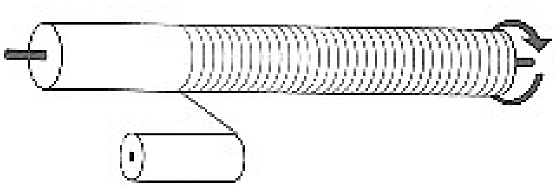
angle between fiber and the line on surface of the mandrel

A maximum value - close to 90 degrees

A minimum value –very low winding angle - need some arrangements at the ends of the mandrel, such as pins, etc.



Coupled helical winding of layers ($\pm\theta$) are usually preferred



hoop winding - winding angle, very close to 90°

By varying the winding angle with respect to the mandrel axis, directional strength can be obtained by considering the loads, which will operate on the finished product.

Filament Winding Technique

Advantages	Limitation
– high specific strength, specific modulus and fiber volume percentage of the finished products – an effective way to produce high strength tubes especially when there exists an internal pressure – high repeatability of the process	– the difficulty in production of complex shapes – requirement of very complex mandrel designs

Materials

Thermosetting resin

Epoxy matrix system from Huntsman:
Araldite LY1135-1 is an epoxy resin
Aradur 917 is an anhydride hardener
Accelerator 960 is an amine accelerator

- is a hot-curing,
- low viscosity resin system
- exhibits good wetting properties
- is easy to process
- good chemical resistance

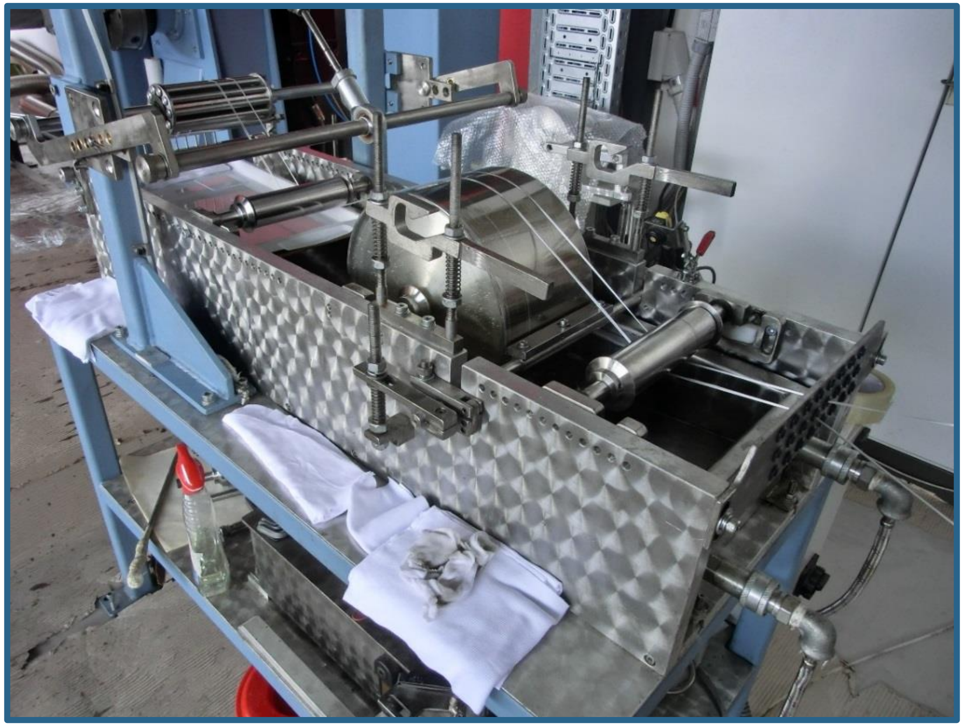
Rovings

- **Glass**
- Carbon
- Polyester
- Aramid

E-glass, continuous filament from Owens Corning – **P185 1200 tex**

Test Specimen Fabrication

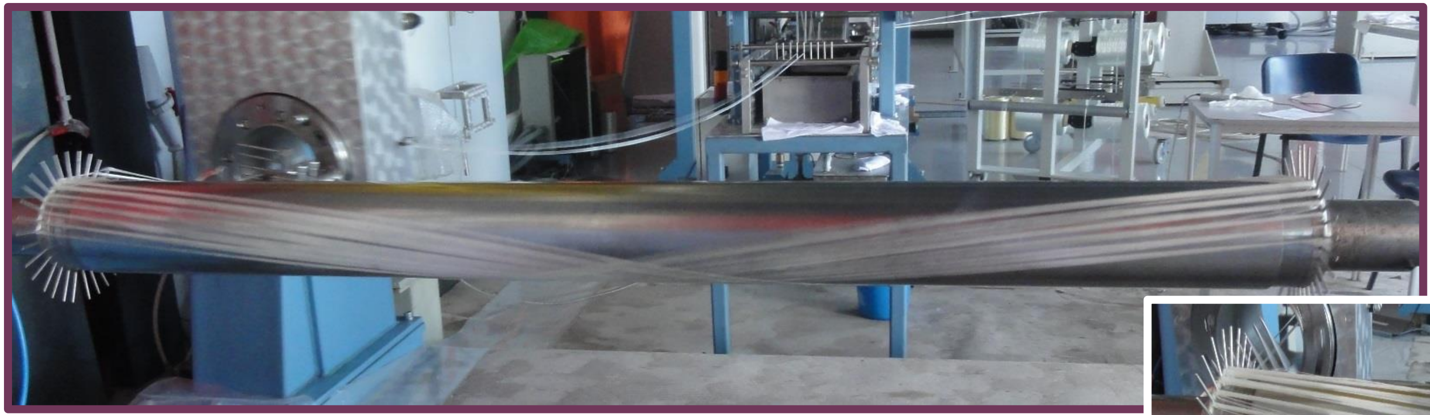
Laboratory at Institute for Advanced Composites and Robotics

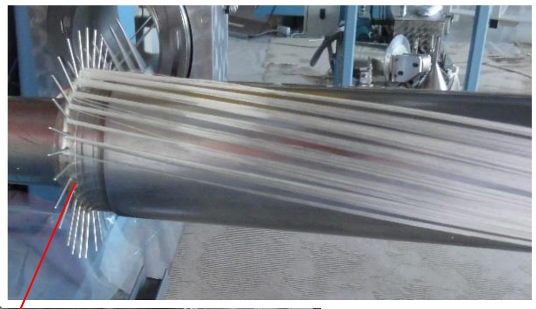


Full factorial experimental design - 2^3

No. exp.	Matrix of full factorial experimental design							Characteristics (conditions of the experiment)		
	X_1	X_2	X_3	$X_1 X_2$	$X_1 X_3$	$X_2 X_3$	$X_1 X_2 X_3$	**X_1 (m/min)** *velocity of the filament winding*	**X_2 (N)** *fibre tension*	**X_3 (^{0})** *winding angle*
1	-1	-1	-1	+1	+1	+1	-1	5,25	64	10
2	+1	-1	-1	-1	-1	+1	+1	21	64	10
3	-1	+1	-1	-1	+1	-1	+1	5,25	110	10
4	+1	+1	-1	+1	-1	-1	-1	21	110	10
5	-1	-1	+1	+1	-1	-1	+1	5,25	64	90
6	+1	-1	+1	-1	+1	-1	-1	21	64	90
7	-1	+1	+1	-1	-1	+1	-1	5,25	110	90
8	+1	+1	+1	+1	+1	+1	+1	21	110	90

Primary level	X_1 = 13,125	X_2 = 87	X_3 = 50
Interval of variation	7,875	23	40
Lower level	5,25	64	10
Upper level	21	110	90





$X_1 = 21$ m/min
$X_2 = 64$ N
$X_3 = 10^0$

A minimum value –very low winding angle - need some arrangements at the ends of the mandrel, such as pins, etc.

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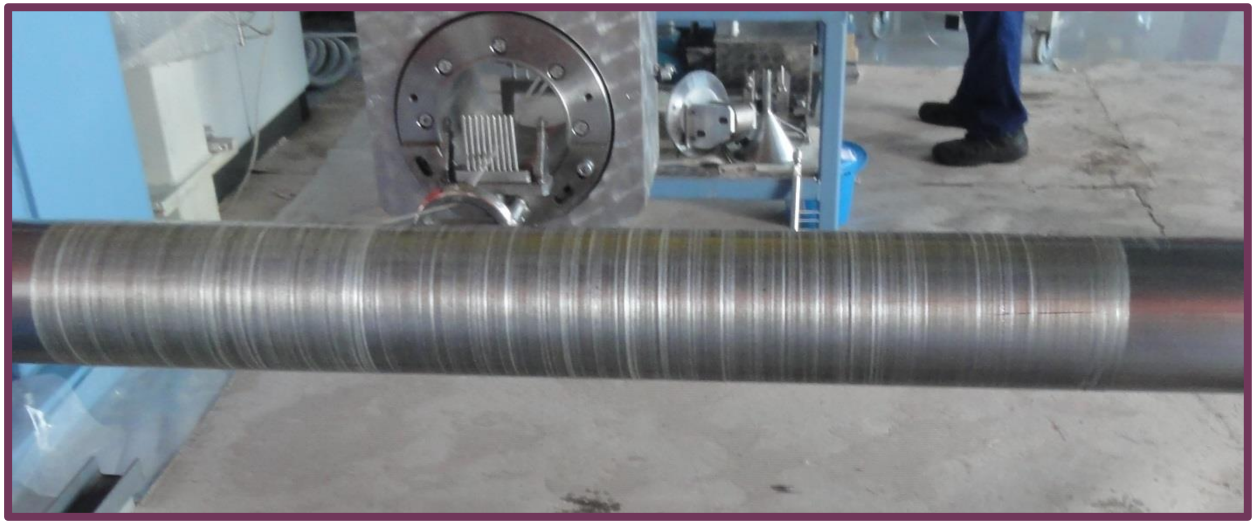
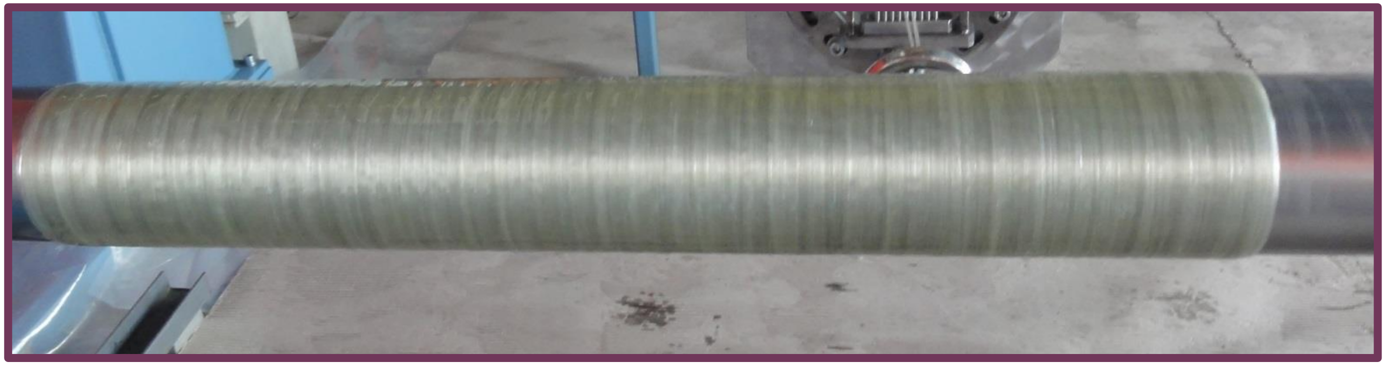
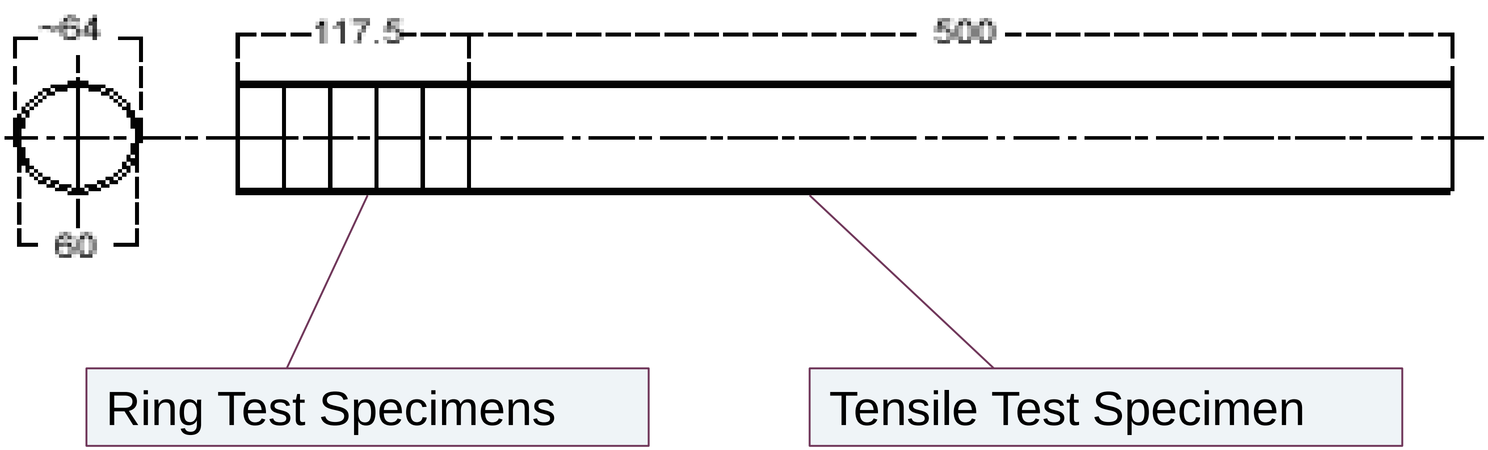




X_1 = 21 m/min
X_2 = 110 N
X_3 = 90^0

- two-step curing program were determined:
  - *curing at 80°C, for four hours*
  - *curing at 140°C, for four hours*
- removal of the mandrel from the specimens
- each specimen was then cut so as to obtain five split-disk test specimens and a tensile test specimen



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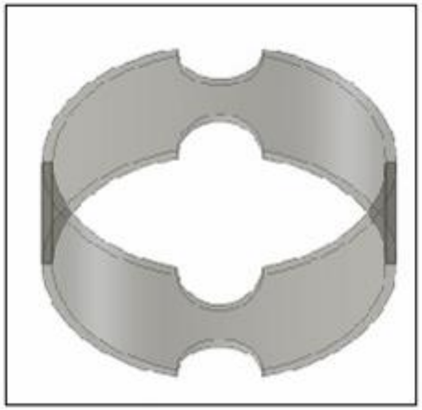
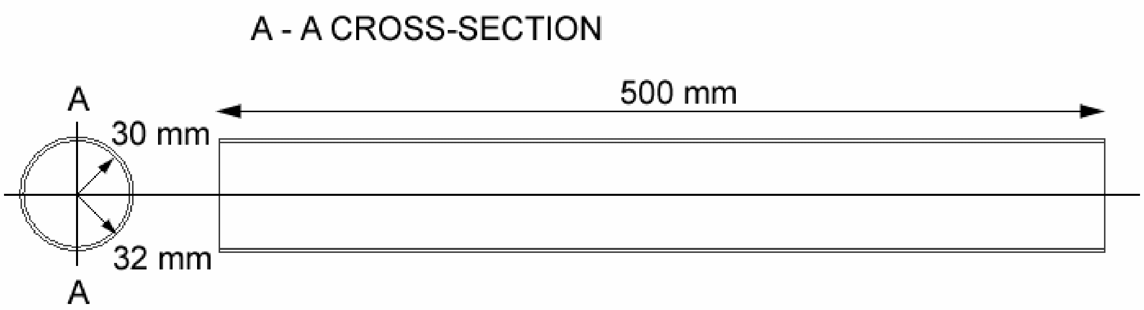
Experimental Technique

Determination of:

- hoop tensile properties by split disk method (ASTM D 2290)
- longitudinal tensile properties (ASTM D 2105)



split disk test specimen



tensile test specimen

Application in construction

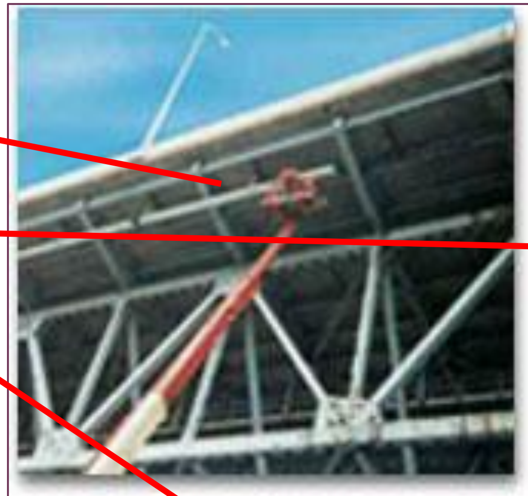
filament wound glass reinforced plastic (GRP) pipes

GRP rebar, beams, decks, safety barriers, rebar for concrete bridge decks, parapets, retaining structures, to reinforce concrete columns etc.

Application in construction

Corrosion Resistant
Lightweight
Ease of Installation
Custom Fabrication

filament wound glass reinforced plastic (GRP) pipes filament wound glass reinforced plastic (GRP) pipes



Thank you

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