

# CORDENKA

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## Fibers Considered for (Ultra) High Performance Tires

Workshop Cordenka GmbH Techtexil  
Frankfurt

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# Fibers for (U)HP Tires

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## Common denominator

- **Safeguarding Tire Integrity and Precise Tire Geometry in all stages under and after all circumstances**

## Standards to beat by any candidate material

- **Steelcord, Aramid and Rayon  
(Tire manufacturing process leaves role for Polyamide)**

# Basics Reinforcing Materials

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## High tensile properties

- achieved by *orientation*  
(steel by drawing and cabling; textiles by spinning and twisting)

## Flexibility

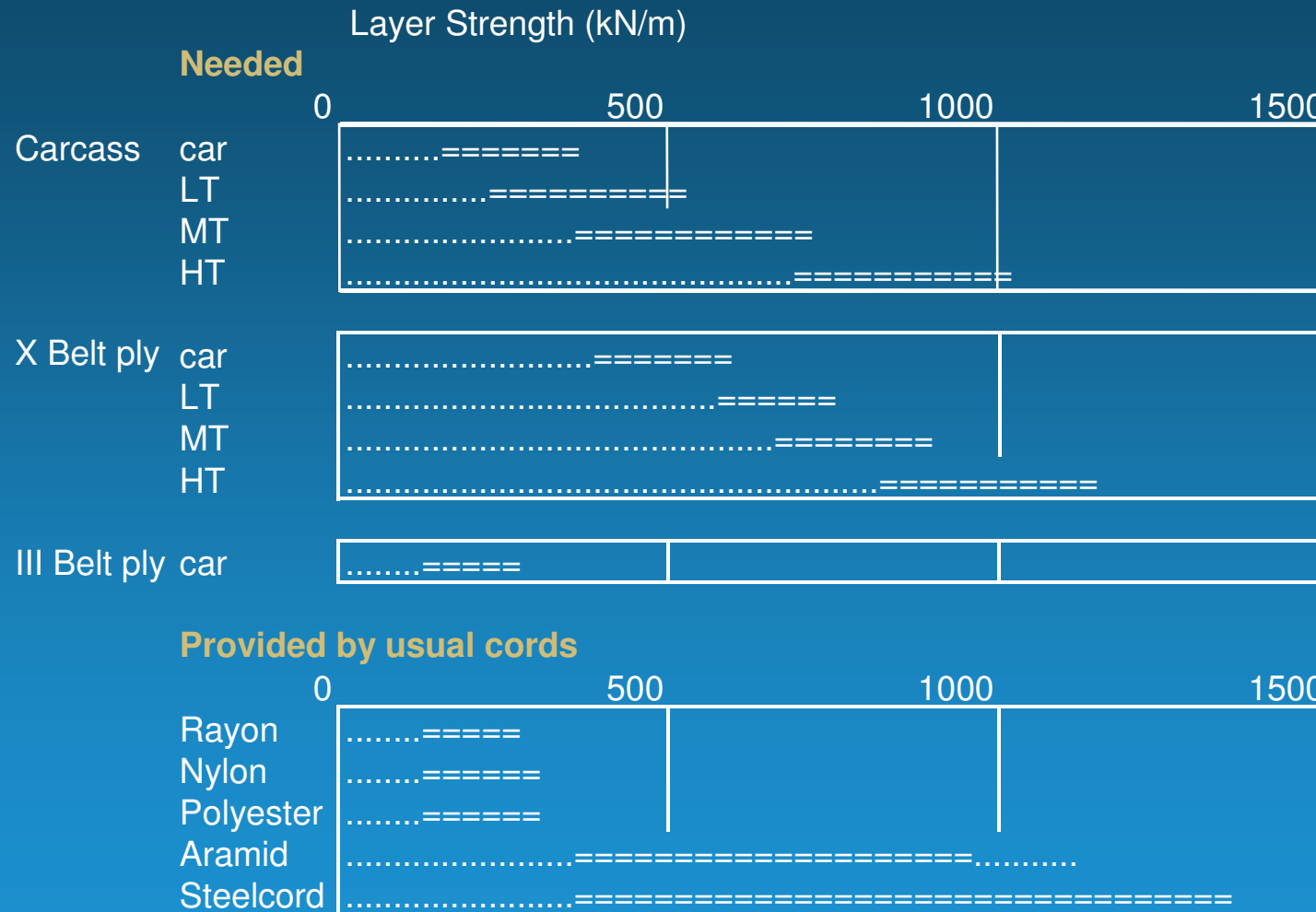
- Bundle or cord principle
- Thin filaments
- Adequate impregnation

## Fatigue resistance

- Material structure
- Size filament
- Helix angle ("lay length"/ "twist")
- Adequate impregnation

## Durable adhesion to rubber

# Strength needed and provided



# Essential Criteria for Reinforcement in Tire Parts

	Carcass	X Belt layers	IIII Belt layer(s)
No thermal shrinkage	Yes	Yes	Depending
High tensile modulus	Yes	Yes	After curing: yes
Compression modulus	No	Preferably	No
High flexibility	Yes	Refer compr. mod.	Yes
No creep	Yes	Yes	Yes
High elongation at break	Yes	No	Preferably
Low work loss	Yes	Yes	Yes
Low flat spotting	Yes	Yes	Yes

## Also Essential for Reinforcing Self-Supporting Run-Flat Tires

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- **Bead core for highest bead seat security**
- **Mechanical properties and adhesion at high temperature**
- **Belt package contributing to enveloping capability**
- **Weight saving (low number of thin layers)**
- **Keeping rolling resistance low**

# Intrinsic: Structure Materials

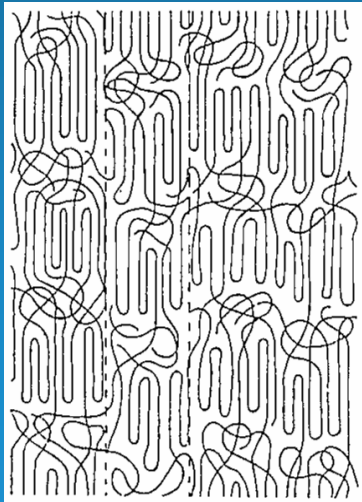
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## Semicrystalline

(meltspun)

**Polyamide (PA 6, PA 6.6)**

**Polyester (PET)**



## Paracrystalline

(wetspun)

**Aramid**

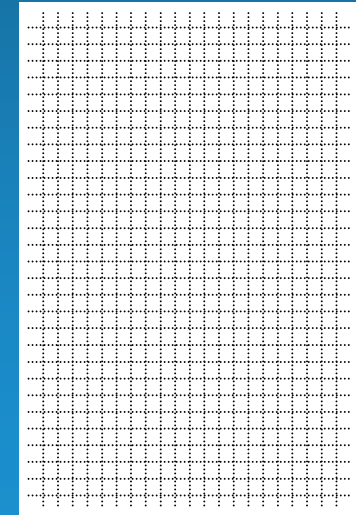
**Cellulose (Rayon)**



## Crystalline-3D

(drawing)

**Steel wire**



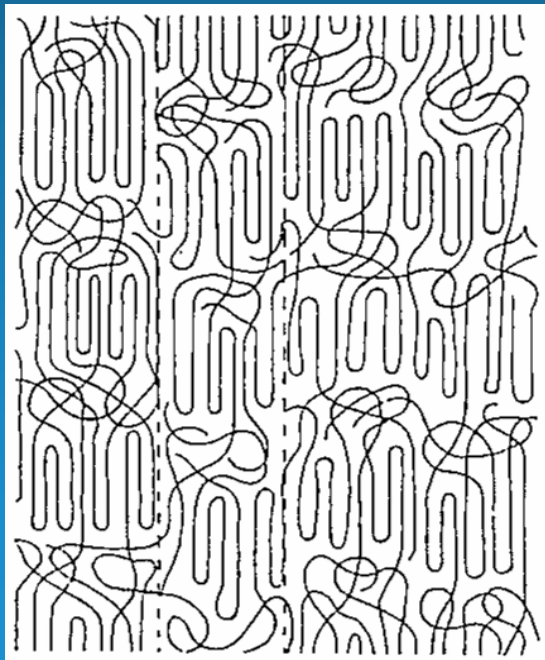
# Intrinsic: Structure Meltspun Materials

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- **Semicrystalline (meltspun)**

**Polyamide (PA 6, PA 6.6)**

**Polyester (PET)**



moderate strength  
moderate modulus  
high elongation at break  
shrinkage  
creep  
no compression modulus  
high flexibility

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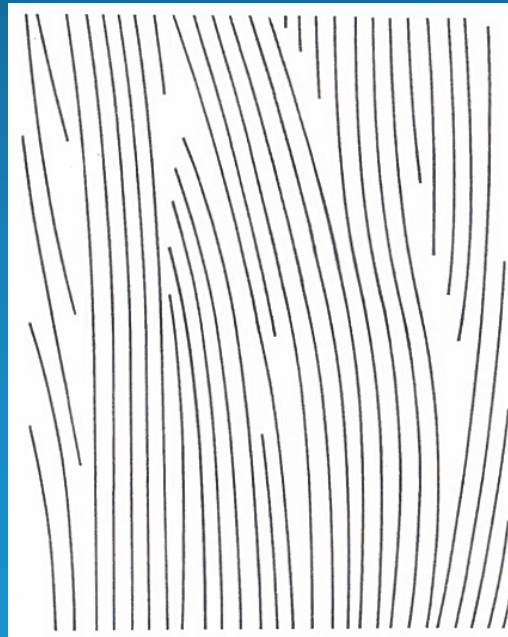
# Intrinsic: Structure Wetspun Materials

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- **Paracrystalline (wetspun)**

## **Aramid**

**very high strength  
very high modulus  
small elong. at break  
no shrinkage  
no compr. modulus  
high flexibility**



## **Cellulose (Rayon)**

**moderate strength  
high mod./strength  
high elong. at break  
no shrinkage  
no compr. modulus  
high flexibility**

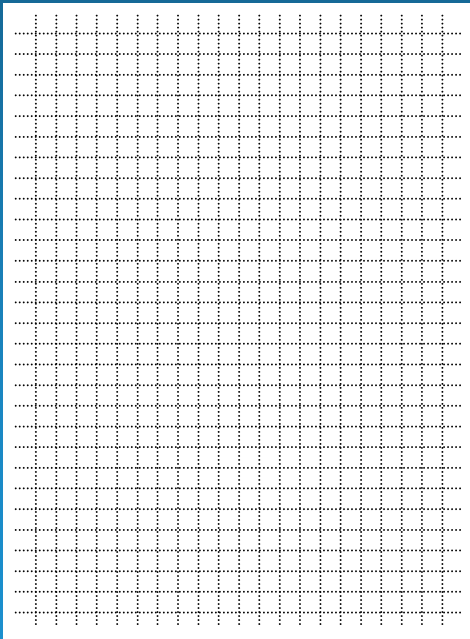
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# Intrinsic: Structure Materials

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- **Crystalline -3D**

## Steel



**very high strength**  
**very high modulus**  
**small elongation at break**  
**no shrinkage**  
**no creep**  
**compression modulus**  
**limited flexibility**

# Intrinsic: Structure Materials

## More Candidate Materials

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### Semi-crystalline

(melt spun)

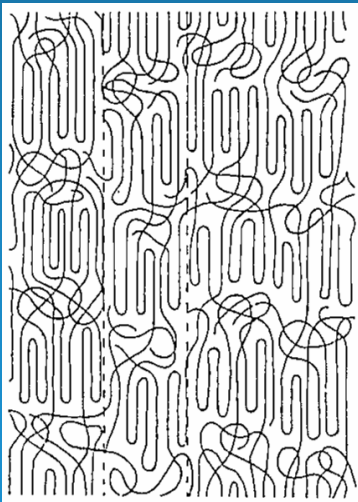
**PEN**

**Beltec**

**Rayon-like PET**

**PA4.6**

**(POK)**

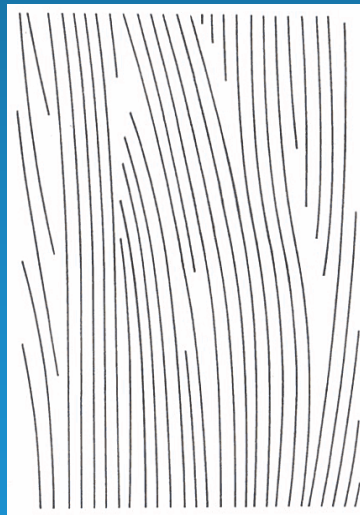


### Para-crystalline

(wet-spun)

**(Lyocell)**

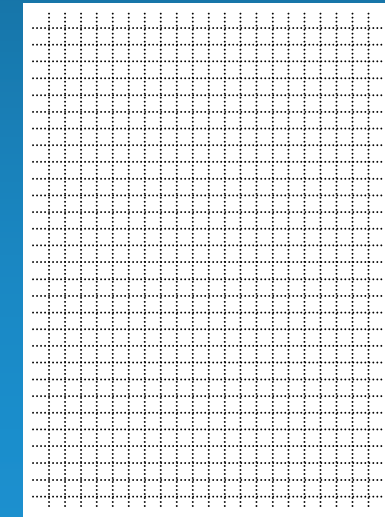
**(POK)**



### Crystalline-2D

(precursor heating)

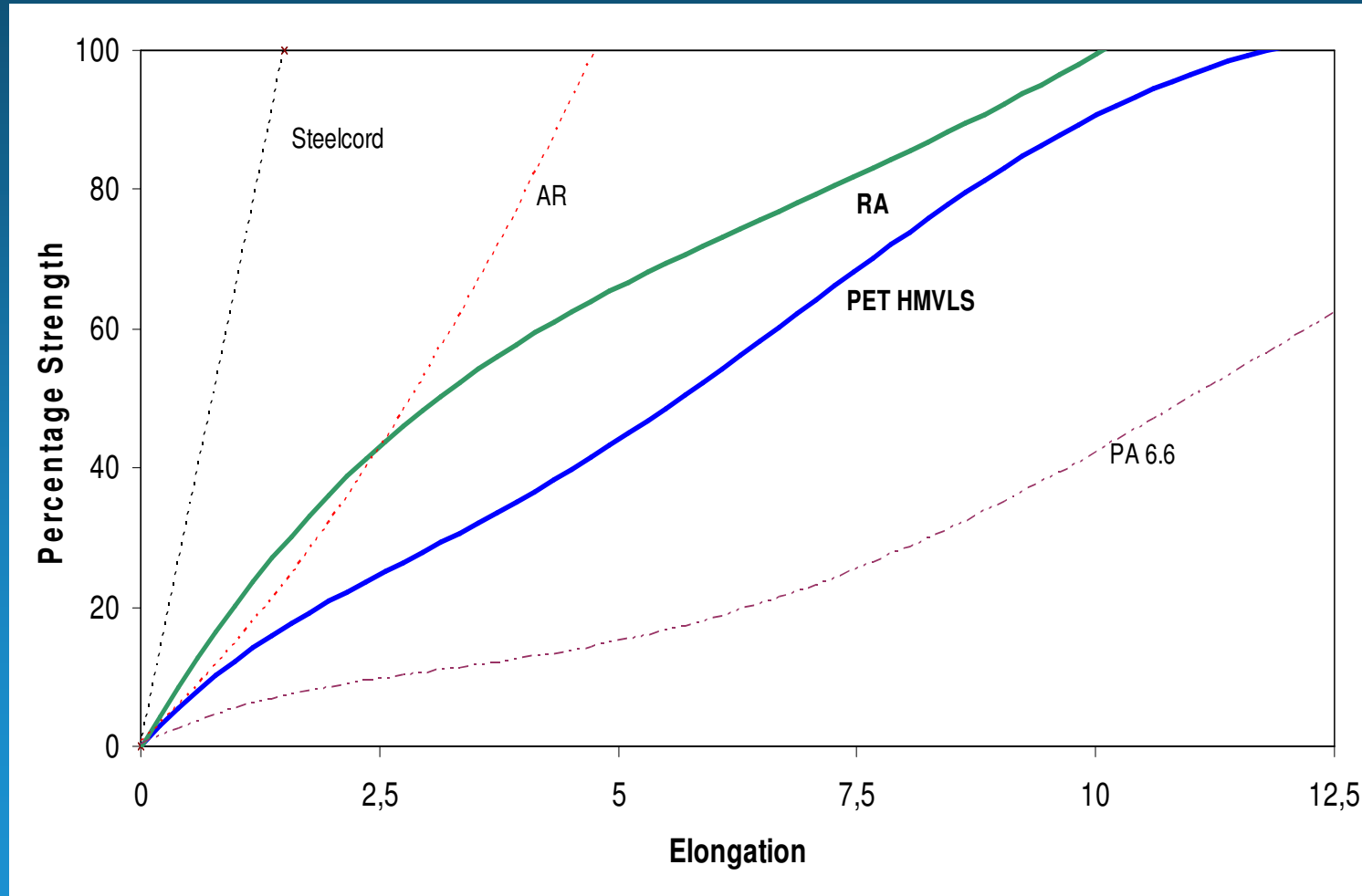
**Carbon fiber**



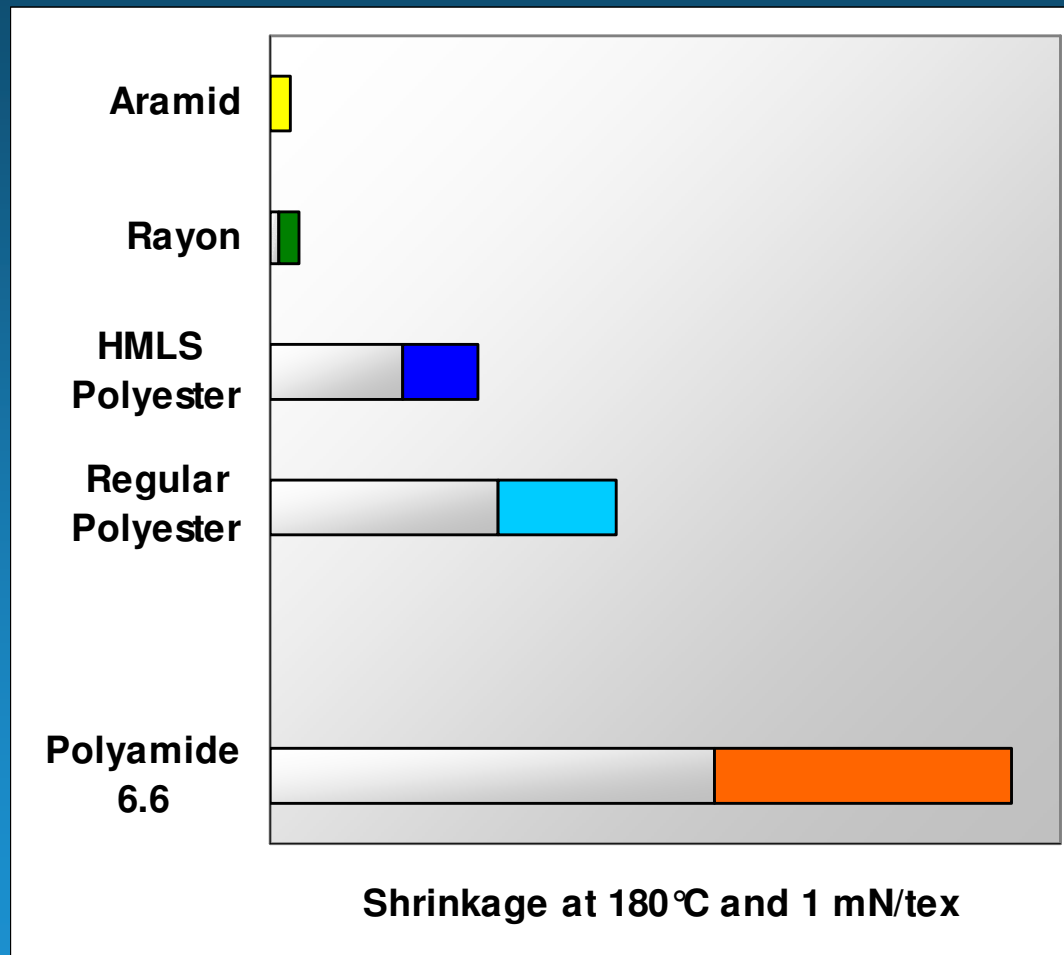
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# Designing Carcass of Certain Strength

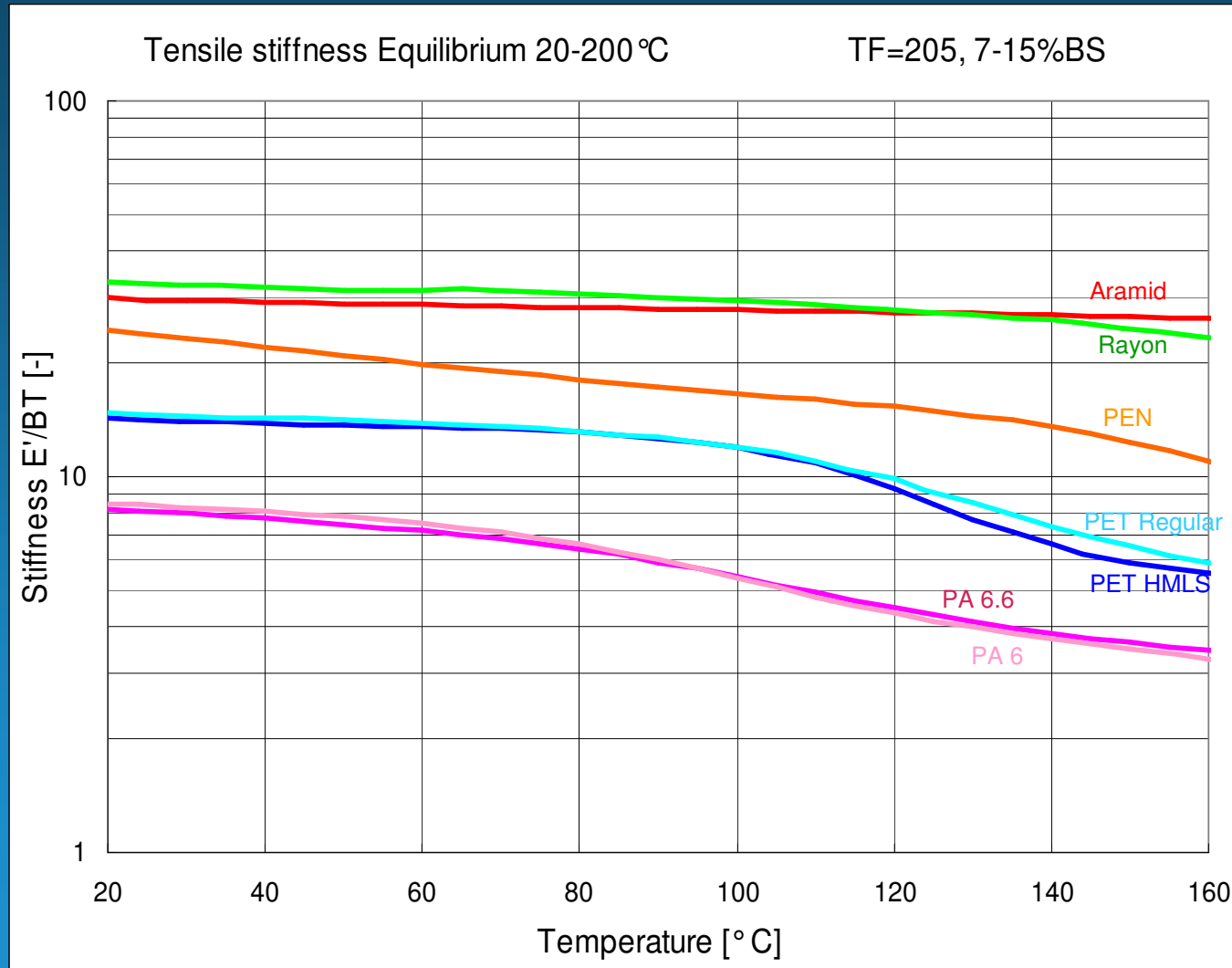
## Materials ready for rubberizing



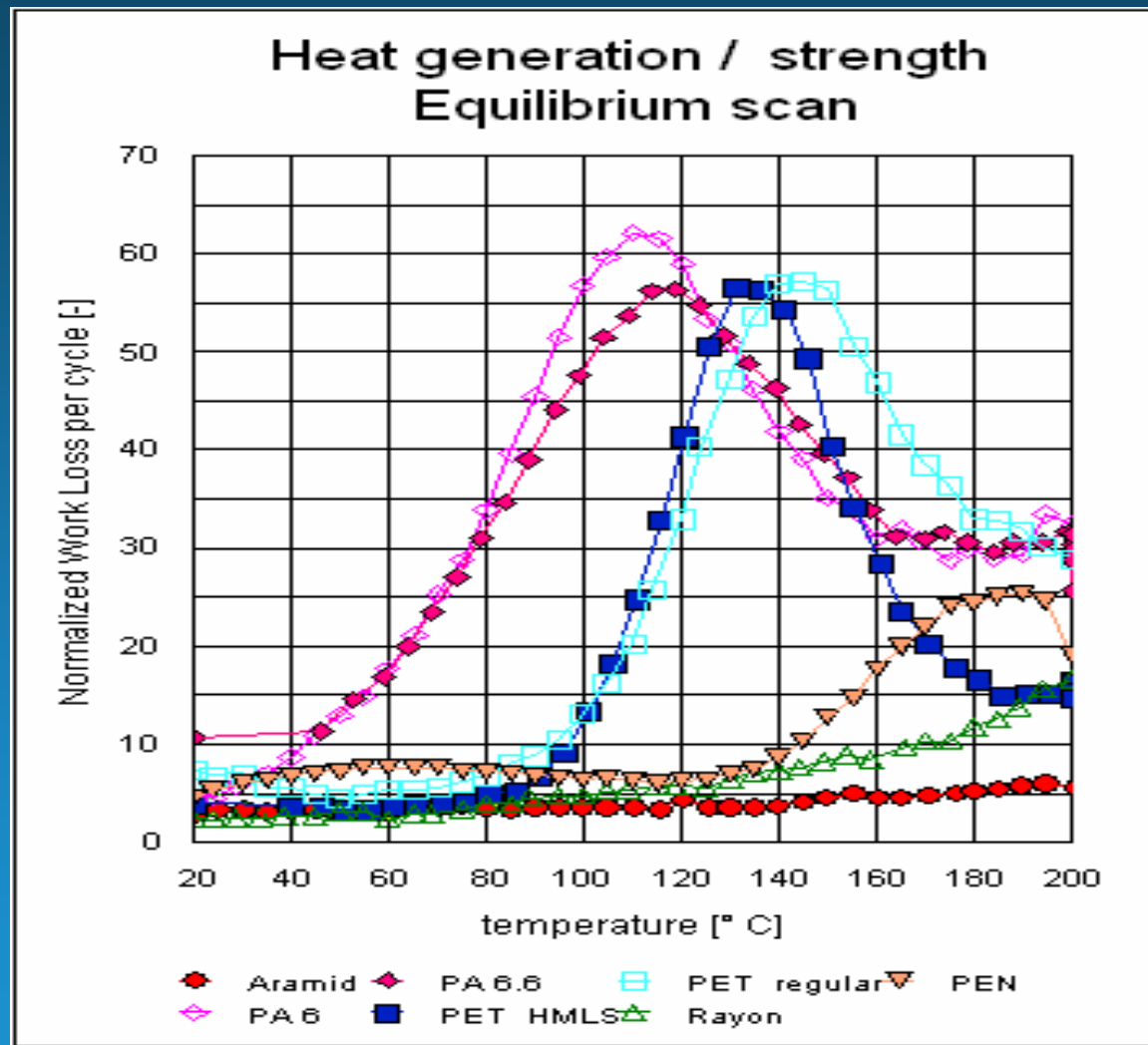
# Wetspun vs. Meltspun Thermal Shrinkage Carcass



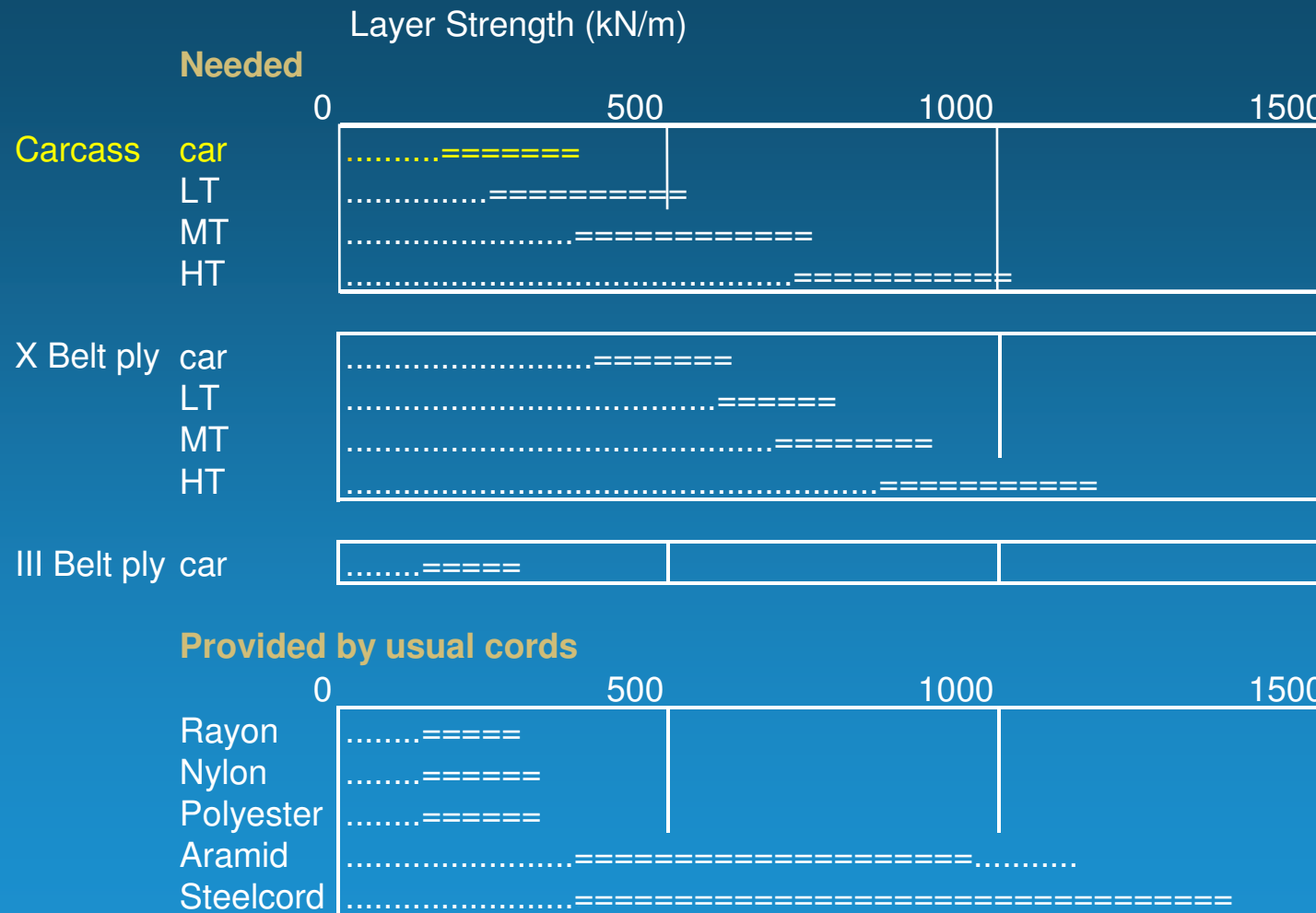
# Wetspun vs. Meltspun Dynamic Modulus/ Strength Carcass



# Wetspun vs. Meltspun Work Loss/ Strength Carcass



# Carcass Car Tire



# Carcass Car Tire

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## Status

- Rayon used in HP- and UHP-tires
- H MVLS polyester in standard tires
- (Polyamide replaced)
- (Steelcord and aramid not used)

# Considering Fibers for Car Tire Carcass

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## Aramid and Steelcord

- Over-designing ("far too strong") unless with unusually thin cords
- Elongation at break far below that of materials applied

## Steelcord

- Difficult in current car tire assembly (turn up; compression modulus under belt)
- Difficult combination of thin cord, thin filaments, small lay length for fatigue resistance with rubber penetration for corrosion protection

# Considering Fibers for Car Tires

## Carcass

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- **PA 6.6** just in slightly crossed layers in "street-racing" tires
- **PET HMVLS** current commodity for standard tires
- **PEN HM** at RT better than PET but declining at relatively moderate temperature; shrinkage compared to PET not VLS
- **POK** if gelspun economics prohibitive; if meltspun modulus/strength, shrinkage, cost worse than PET HMVLS
- **Rayon** copes with all criteria for (U)HP tires
- New cellulosic?

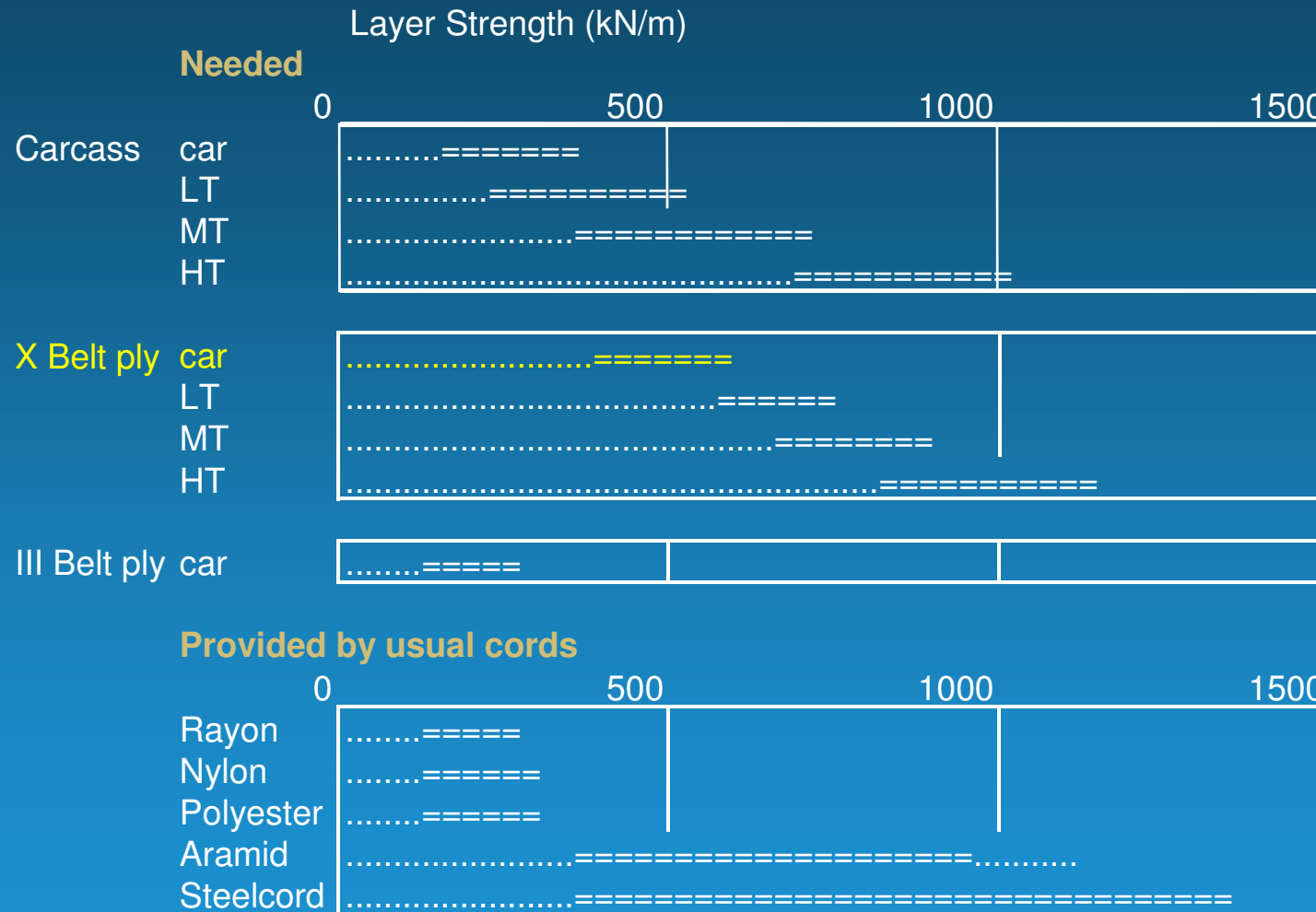
# New Cellulosic Compared to Rayon

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## Lyocell vs Rayon

- Application for apparel
- Product patent Cordenka GmbH for technical application
- Comparable tenacity tire cord
- Higher modulus
- Lower fatigue resistance
- Lower elongation at break
- Cost (basis no depreciation) comparable to rayon

# Crossed Belt Layers Car Tire



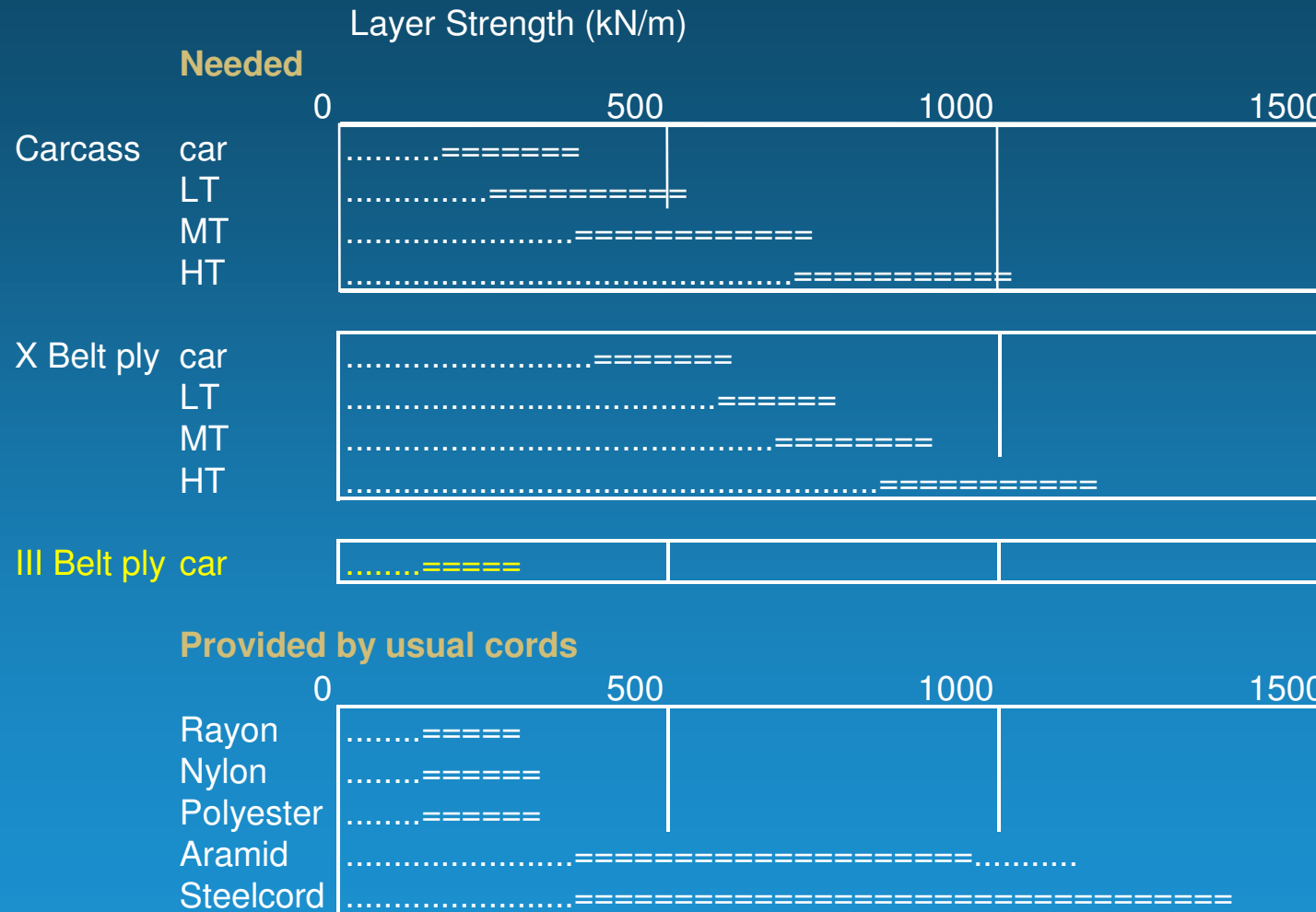
# Considering Fibers for Car Tire

## Crossed Belt Layers

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- **Steelcord** of various constructions from a range of filament diameters
- **Carbon fiber** (composite) could be light weight alternative
- **Aramid cords in both crossed layers**
  - Lower modulus than steelcord but acceptable
  - No compression modulus drawback for cornering stiffness and wear resistance
  - Flexibility for enveloping capability
  - Low mass but more rubber required
- **Aramid cords in part of crossed layers**  
(“C-fold” belt expelled by wound cap ply)
  - Ideas in patents (e.g. aramid and steel cord side by side in one layer; one cut aramid layer and one cut steelcord layer)

# Cap Ply Car Tire



# Considering Fibers for Car Tire

## Zero Degree Belt Layer(s) ('Cap ply')

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- **Polyamide 6.6 (PA 6.6)**
  - Low modulus enabling lift uncured tire
  - Shrinkage useful during tire curing
  - Reversibility shrinkage useful during tire service (shrinkage tension)
- **Polyamide 4.6 (PA 4.6)**
  - Relatively small differences with PA6.6
- **Polyester (PET)**
  - Tensile modulus > PA6.6
  - Shrinkage less reversible

# Considering Fibers for Car Tire

## Zero Degree Belt Layer(s) ('Cap ply')

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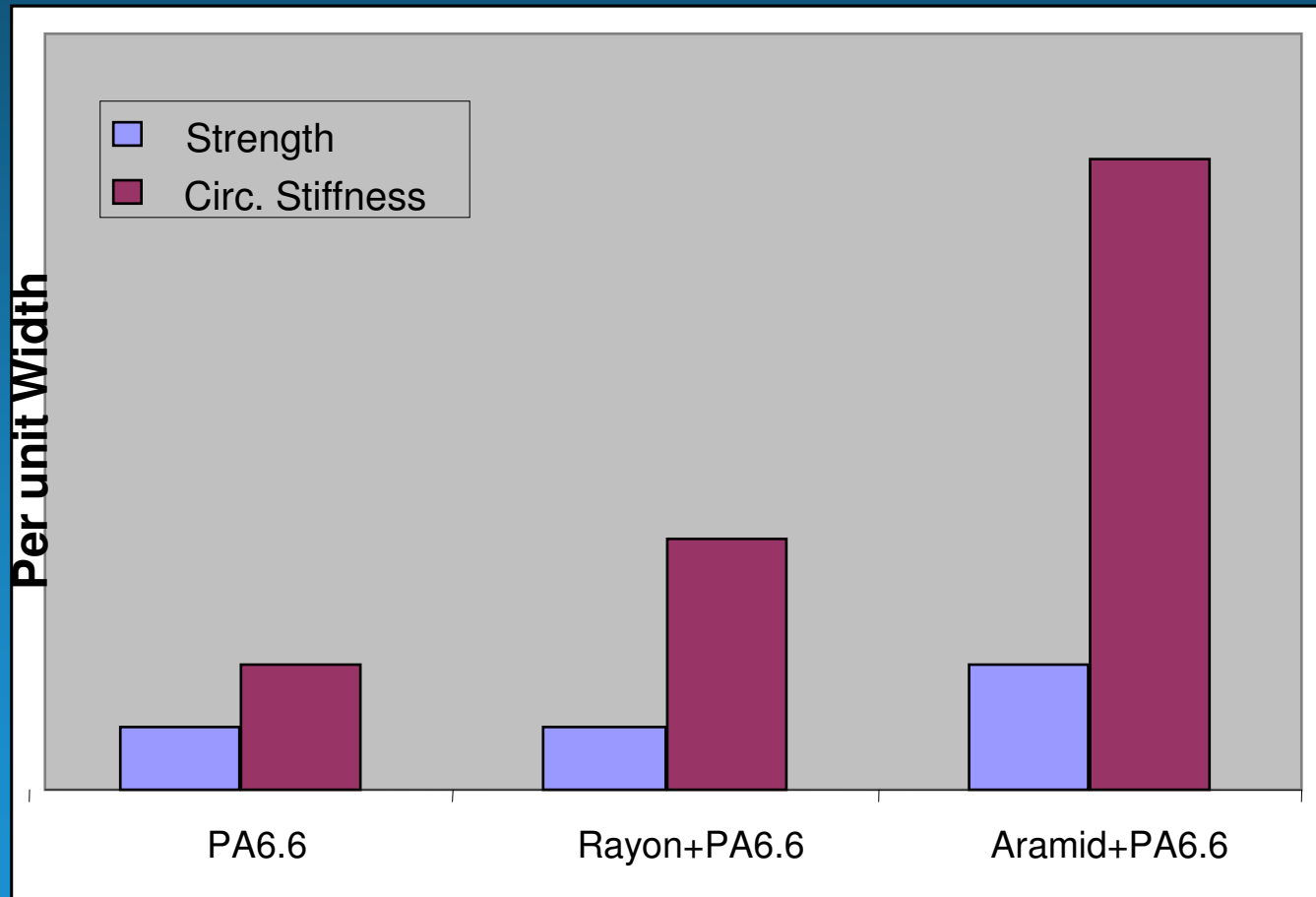
- **PEN (polyethyleneterephthalate)**
  - HM at RT better than PET but declining at relatively moderate temperature
  - Shrinkage compared to PET HMVLS not VLS
- **Aramid**
  - High modulus hampers lift uncured tire
  - High modulus useful in tire service
  - No shrinkage during curing to be taken into account
  - Over-designing
- **Hybrid cord Aramid+PA 6.6**
  - Combines easy lift uncured tire and high modulus in tire service
  - In cases over-designing
- **(Hypothesis) Hybrid cord Rayon+PA 6.6**
  - Could fill gap
  - (no over-designing)

# Considering Fibers for Car Tire

## Zero Degree Belt Layer(s) ('Cap ply')

Cap ply Positioning

Hybrid Cord Rayon + PA 6.6



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# (U)HP Today/Tomorrow

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- **“Better than today”**  
(adoption new consumer desires; e.g. (U)HP winter tires)
- **Very fast SUV-tires**  
(very large, fast car tires)
- **C-type tires for very fast vans**  
(two service descriptions and “for the sake of safety with rayon”)

# (U)HP Today/Tomorrow

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- **Run-Flat**
  - Carcass with guaranteed stability and adhesion to rubber at very high temperature
  - Low work loss (heat generation) carcass
- **Better enveloping capability of low aspect tires**
  - E.g. larger XX angles
  - Larger XX angles call for more stable cap ply
    - Aramid; Aramid+PA6.6; Rayon+PA 6.6?

# (U)HP Today/Tomorrow

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- **TREAD Act**
  - Carcass stability and adhesion to rubber required at higher temperature due to allowed pressure drop
- **Low Rolling Resistance**
  - Low work loss (heat generation) of material valuable asset

# Fibers for (U)HP Tires

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## Common denominator

- **Safeguarding Tire Integrity and Precise Tire Geometry in all stages under and after all circumstances**

## Standards to beat by any candidate material

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# Essential Criteria for Reinforcement in Tire Parts

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Compression modulus	No	Preferably	No
High flexibility	Yes	Refer compr. mod.	Yes
No creep	Yes	Yes	Yes
High elongation at break	Yes	No	Preferably
Low work loss	Yes	Yes	Yes
Low flat spotting	Yes	Yes	Yes

# Essential Criteria Reviewed for Rayon

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- **Thermal shrinkage negligible**
- **Modulus/ Strength ratio high till very high temperature**
- **No compression modulus**
- **Flexibility high**
- **Creep almost inexistent**
- **High elongation at break**
- **Low work loss (no self inducing temperature rise)**
- **Negligible share in flat spotting**
- **(Adhesion to rubber easy and durable)**

**Rayon copes with criteria for (U)HP tires**

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# Audience

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Thank you for your attention!

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