Toho Tenax America

November 13th, 2014
Painel Aeroespacial

"From Carbon Fiber to Carbon Fiber Reinforced Thermoplastic"

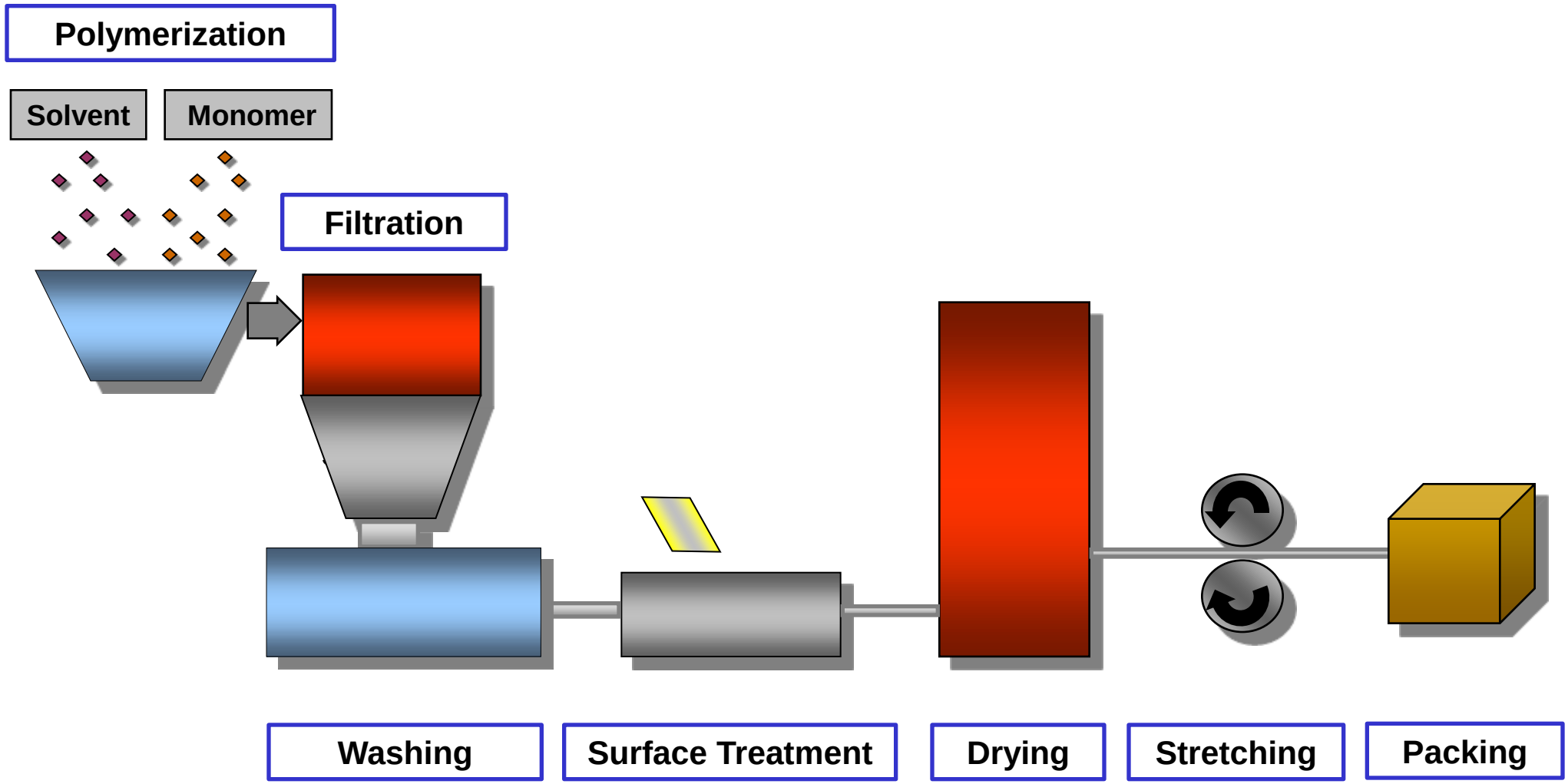
Rodrigo Cesar Berardine
Sales and Marketing Manager
South America

São Paulo - Brazil

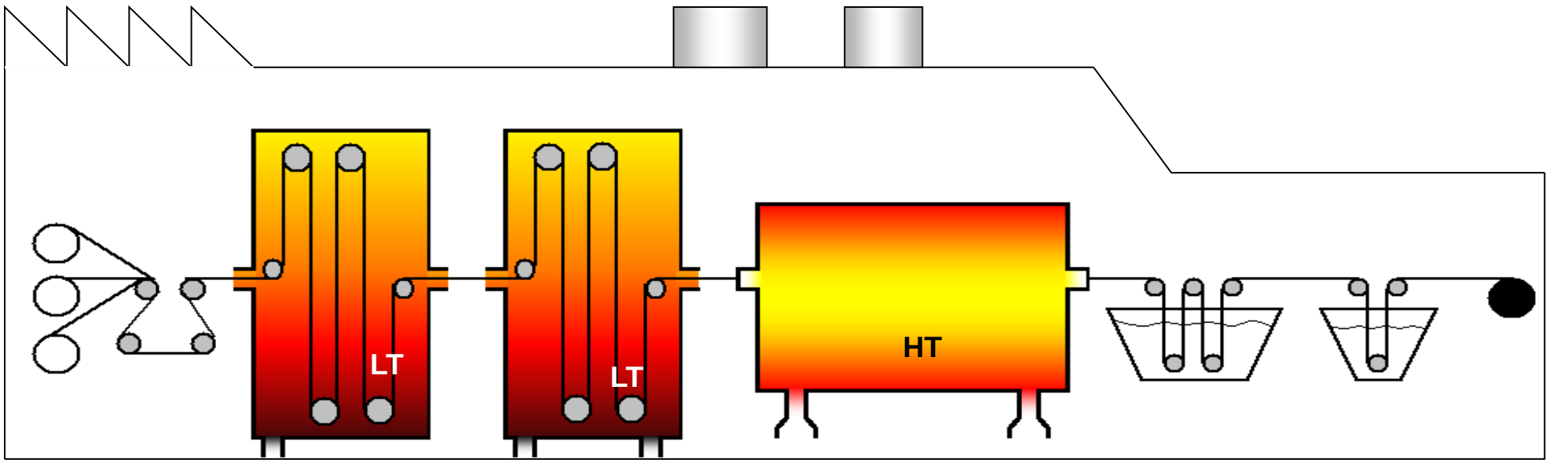
Content

- Carbon Fiber production and properties overview
- Thermoplastics versus Thermosets
- Importance of sizings for Thermoplastics
- Thermoplastic UniDirectional Tapes (TPUD)
- Thermoplastic Woven Fabrics (TPWF)
- Thermoplastic Consolidated Laminates (TPCL)

Precursor (PAN) Production Process



Carbon Fiber Production Process

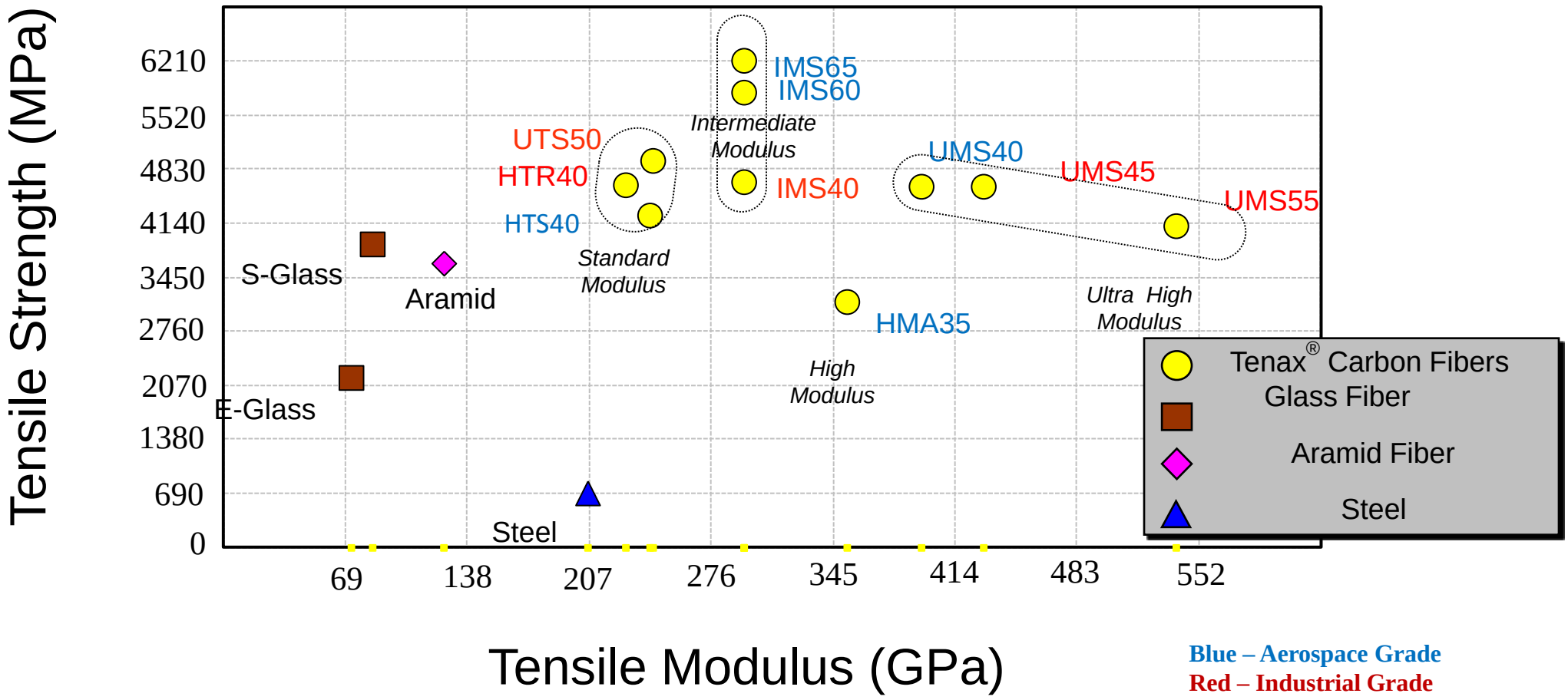


Stretching	Oxidation	Carbonization	Surface Treatment	Winding

- Complex chemical plant: nitrogen, energy, toxic exhaust fumes
- Substantial plant size 200m length, 18m height
- Three shift, 24 hours production process on 360 day/year
- 2kgs of PAN for 1kg of carbon fiber

Tenax carbon fiber production line

Reinforcement Products



Blue – Aerospace Grade
Red – Industrial Grade


Tenax® ThermoPlastics

Thermoplastics versus Thermosets

	Thermoplastic	Thermoset
Room temperature storage	✓	X
Long-term storage	✓	X
Transport conditions	✓	X
Health and safety friendly	✓	X
Short process time	✓	X
Low Viscosity	X	✓
Low processing Temperature (< 200 ° C)	X	✓
Reformable	✓	X
Recyclable	✓	X *more difficult

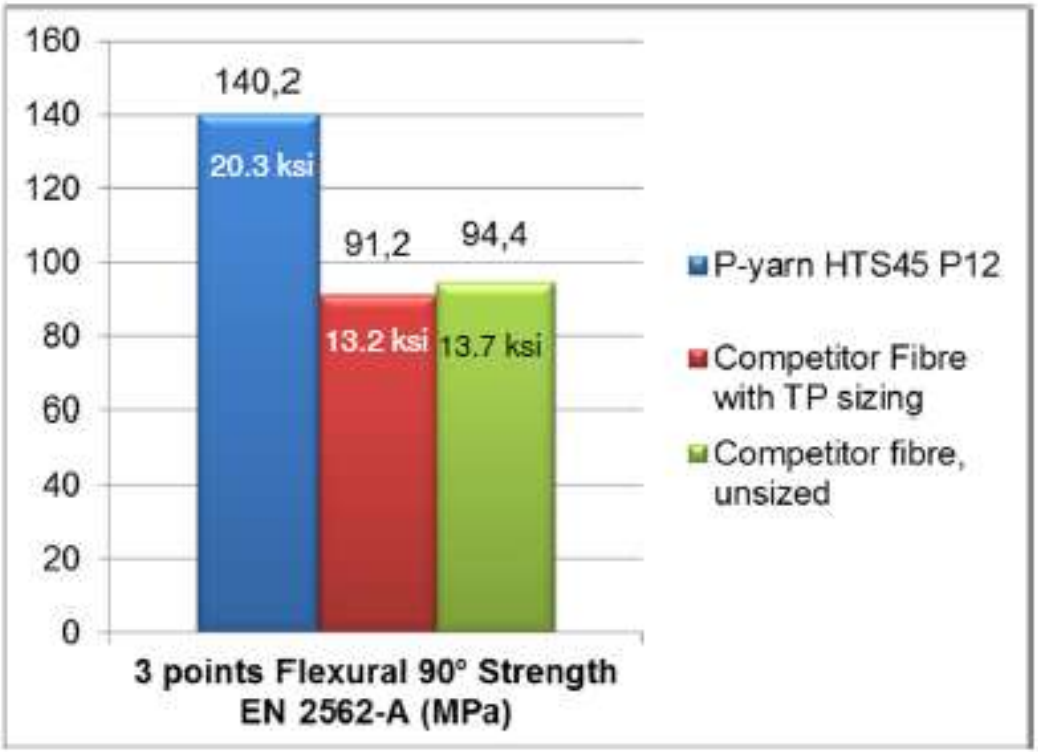
Intrinsic Properties

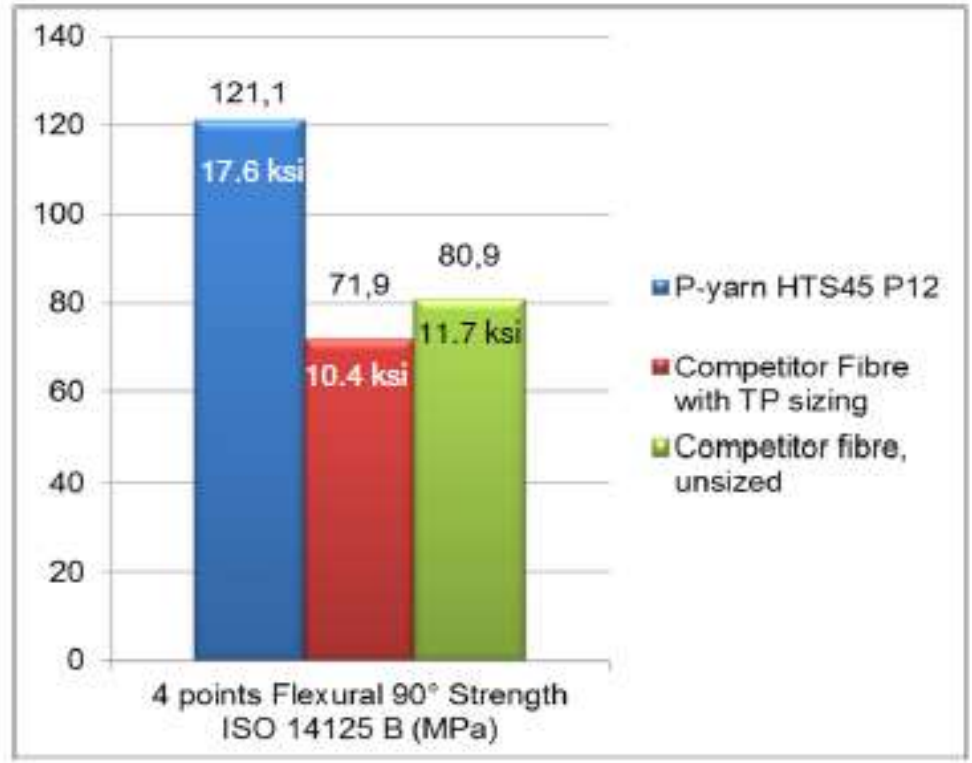
IMPORTANCE OF CARBON FIBER SIZINGS FOR THERMOPLASTICS

Thermoplastic Unidiretional tapes comparison

Mechanical comparison:

Test done on laminates produced using PEEK film stacking and static press.

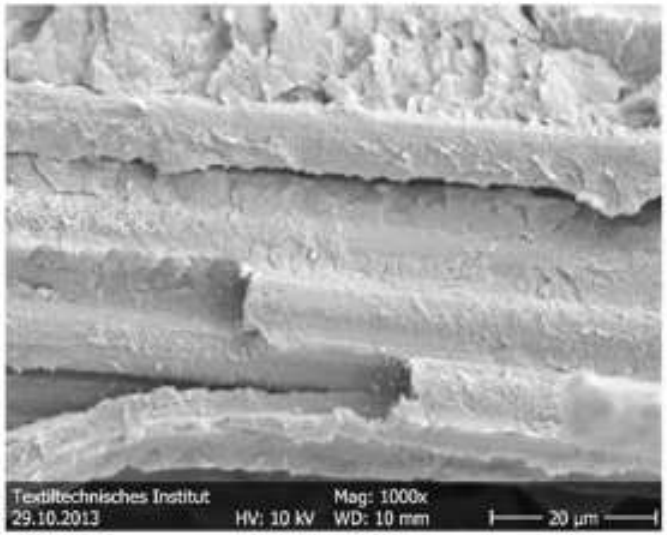




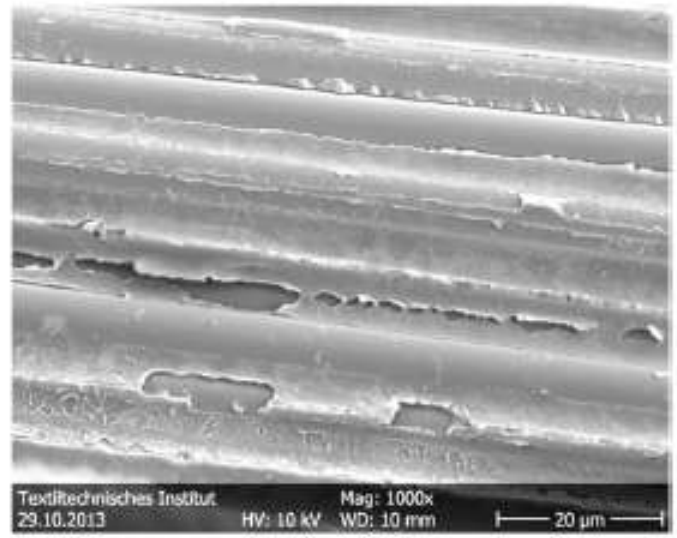
SEM Pictures

SEM pictures:

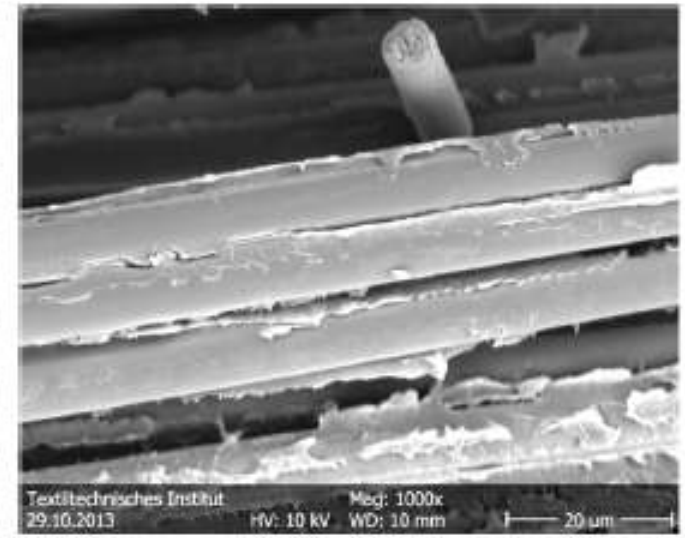
Confirm the improvement of the fiber/matrix adhesion using Tenax® HTS45 P12 yarn



Tenax® HTS45 P12



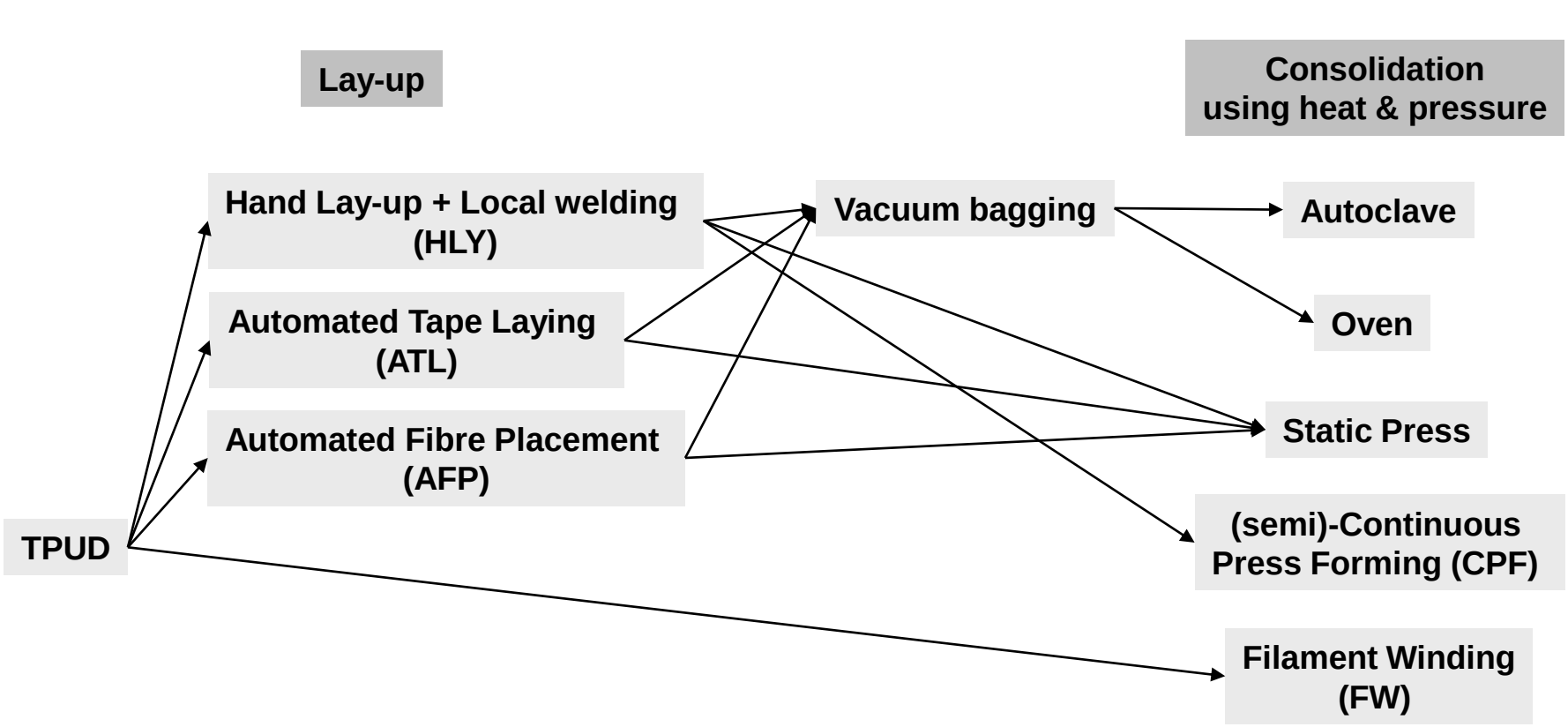
Competitor un-sized fiber



Competitor fiber with TP sizing

ThermoPlastic UniDirectional

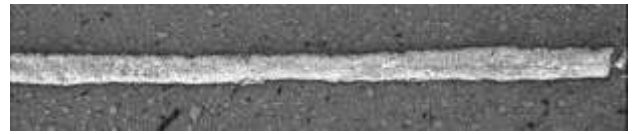
Tenax® TPUD: Part making



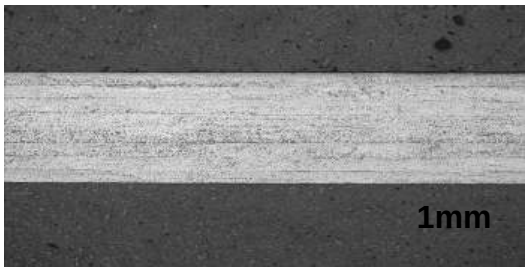
Tenax® TPUD

Tenax®-E TPUD PEEK-HTS40

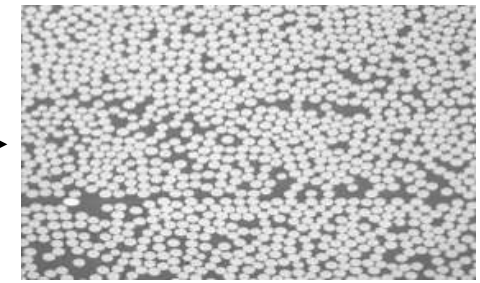
TPUD PEEK-HTS40



Press consolidated laminate



TPUD PEEK-HTS40 laminate
out of 8 plies (+/- 45°)



- Press and vacuum consolidation possible
- Low sensitivity of cristallinity to cooling rate 35 +/- 3 %
- Low void content in TPUD and Laminate < 2 %

TPUD Mechanical Properties

Tenax® TPUD PEEK-HTS45
Laminate Mechanical Properties

→ Equivalent Properties to Thermoset UD-Prepreg (Dry/RT)

→ High fracture toughness

→ Improved Hot/Wet Properties vs. Thermoset (i.e Compr. Strength)

→ Low Moisture Absorption (~ 0.2%) & Reversible

Mechanical Properties (test direction)		Conditioning / Test temperature	Typical value	
Glass transition temperature	onset	23 °C, 50% r.h./ 23 °C, 50% r.h	143 °C	289 °F
Tensile (0°) DIN EN 2561 Type A	modulus	23 °C, 50% r.h./ 23 °C, 50% r.h	142 GPa	20.6 Msi
	strength		2450 MPa	355.3 ksi
Tensile (90°) DIN EN 2597 Type B	strength	23 °C, 50% r.h./ 23 °C, 50% r.h	88 MPa	12.8 ksi
Flexure (0°) DIN 2562 Type A	modulus	23 °C, 50% r.h./ 23 °C, 50% r.h	130 GPa	18.9 Msi
	strength		1760 MPa	255.3 ksi
Compression (0°) EN 2850 Type A3	modulus	23 °C, 50% r.h./ 23 °C, 50% r.h	130 GPa	18.9 Msi
	strength		1545 MPa	224.1 ksi

TPUD Mechanical Properties

Tenax® TPUD PEEK-HTS45
Laminate Mechanical Properties according to ASTM norm

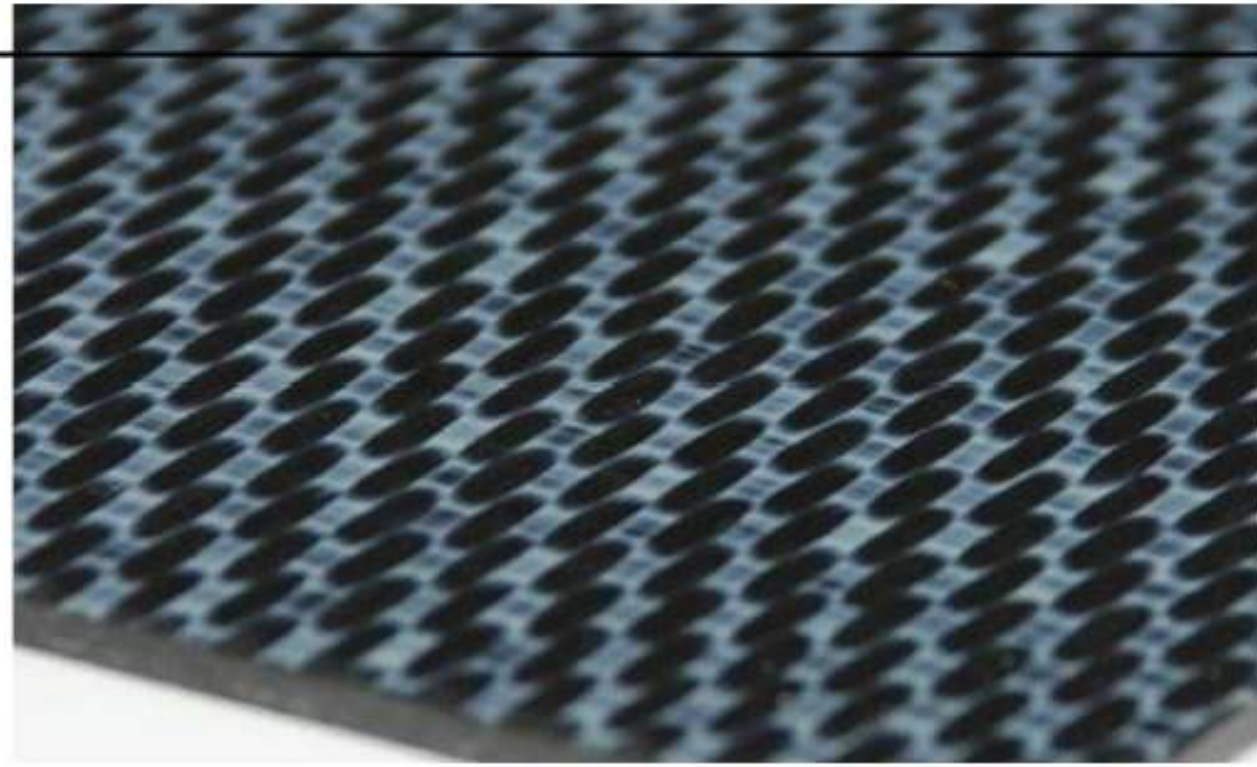
Mechanical Properties (test direction)		Conditioning / Test temperature	Typical value	
Tensile (0°)	modulus	RT /	128 GPa	18.6 Msi
ASTM D3039-07	strength	RT	2240 MPa	325 ksi
Compression CLC (0°)	modulus	RT /	64 GPa	9.3 Msi
ASTM D6641-01	strength	RT	772 MPa	112 ksi
Compression CLC (0°)	modulus	71°C/100% 14 days/	63 GPa	9.2 Msi
ASTM D6641-01	strength	71°C	680 MPa	98.6 ksi
ILSS (0°) ASTM D2344-06	strength	RT / RT	100 MPa	14.5 ksi

ThermoPlastic WovenFabric

Thermoplastic Woven Fabric

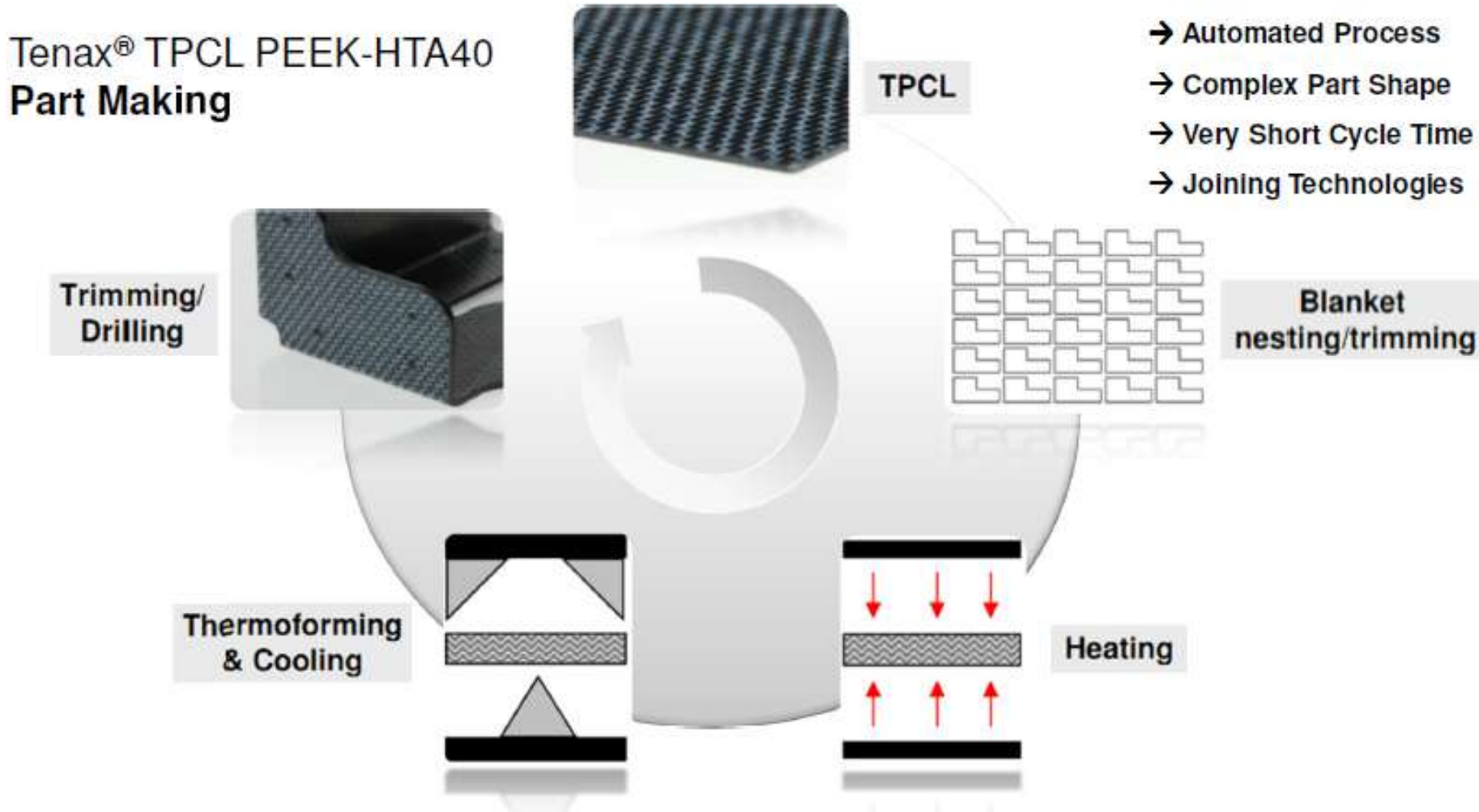
Tenax® TPWF PEEK-HTA40

Technical Characteristics	
Tenax® - E	TPWF PEEK-HTA40
Reinforcement	5HS Fabric
Fiber Area Weight [g/m²]	285
Carbon Fiber	HTA40 3K
Matrix Content [%wt]	42
Matrix	PEEK
Nominal Consolidated Ply Thickness [mm]	0,31 *(12.2mil)*
Width	1250 mm *(49,2")*

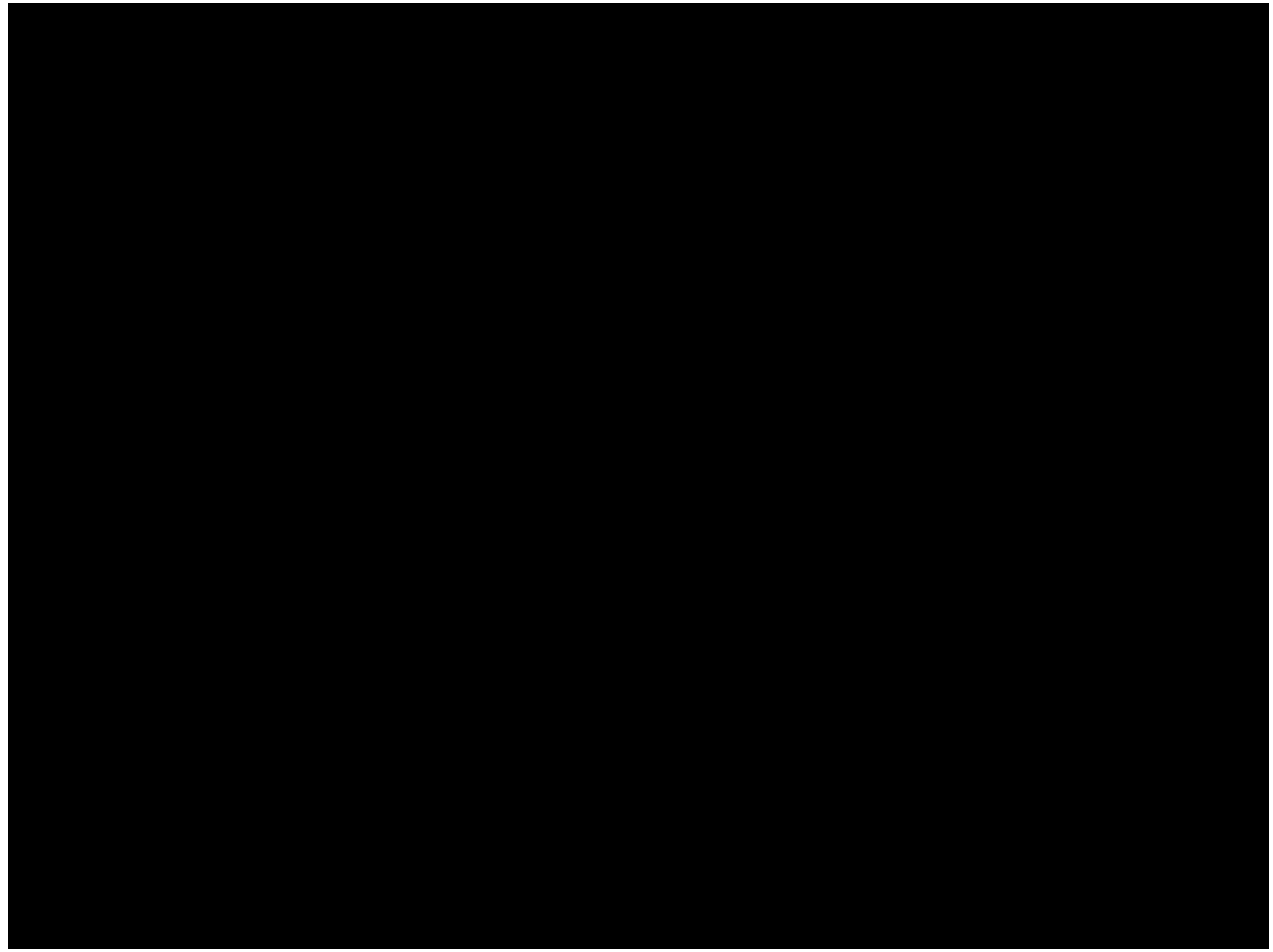


ThermoPlastic ConsolidatedLaminate

TPCL: Part Making



Premium Aerotec Gmbh Corporate Video
TPCL Part Making



Source: Premium Aerotec Website

TPCL Technical Characteristics

Tenax® TPCL PEEK-HTA40
Based on TPWF PEEK-HTA40

Technical Characteristics	
Tenax® - E	TPWF PEEK-HTA40
Reinforcement	5HS Fabric
Fiber Areal Weight [g/m²]	285
Carbon Fiber	HTA40 3K
Matrix Content [%wt]	42
Matrix	PEEK
Nominal Consolidated Ply Thickness [mm]	0,31 *(12.2mil)*
Laminate Size	800 x 1200 mm *(31,5" x 47,3")*
Laminate Thickness	From 1.86 to 4.96 mm (6 to 16 plies) *(From 0.073 to 0.195 in)*

ON BOARD THE A350XWB

Glass Fabric surface ply for Corrosion Protection

Tenax® TPCL PEEK-HTA40
Surface ply: **Glass Fabric**
For Corrosion protection

Technical Characteristics

Material Area Weight	161 g/m²
Glass Fiber Area Weight	105 g/m²
PEEK Content	35 wt%
Fiber Type	E. Style Glass Fiber
Weaving Style	120 Style, 4 HS
Nominal Thickness	0,08mm *(3.15 mil)*

ON BOARD THE A350XWB

Bronze Mesh for LSP

Tenax® TPCL PEEK-HTA40
Surface ply: **Bronze Mesh**
For Lightning Strike Protection

Technical Characteristics

Bronze Mesh Area Weight	230 g/m²
Material	Copper-tin ($CuSn_6$)
Wire Diameter	0.040 mm *(1.57 mil)*
Aperture Width	0.052 mm *(2.05 mil)*
Mesh	275 Aperture/inch
Opening Screening Area	32 %
Nominal Thickness	0.03 mm *(1.2 mil)*

ON BOARD THE A350XWB

TPCL: Mechanical Properties

Tenax® TPCL PEEK-HTA40
Mechanical Laminate Properties

→ Similar Mechanical Properties to Thermoset

Properties (test direction)		Conditioning / Test temperature	Typical value	
Melting point	Peak	DSC	343 °C	649 °F
Glass transition temperature	onset	23 °C, 50% r.h./ 23 °C, 50% r.h	143 °C	289 °F
Tensile[1] (warp, 0°) ISO 527-4	modulus	23 °C, 50% r.h./ 23 °C, 50% r.h	60 GPa	8.7 Msi
	strength		963 MPa	139.7 ksi
Compression[1] (warp, 0°) EN 2850 Type B	modulus	23 °C, 50% r.h./ 23 °C, 50% r.h	59 GPa	8.6 Msi
	strength		725 MPa	105.2 ksi
Flexural (warp, 0°) EN 2562 Type A	modulus	23 °C, 50% r.h./ 23 °C, 50% r.h	64 GPa	9.3 Msi
	strength		1166 MPa	169.1 ksi

[1] normalised to nominal thickness (0,31 mm) *(12.2mil)*

Tenax® TPCL PEEK-HTA40 **ON BOARD OF AIRBUS A350XWB**

Source: Airbus

Thermoplastic Consolidated Laminates

Tenax® TPCL PEEK-HTA40 ON BOARD OF AIRBUS A350XWB

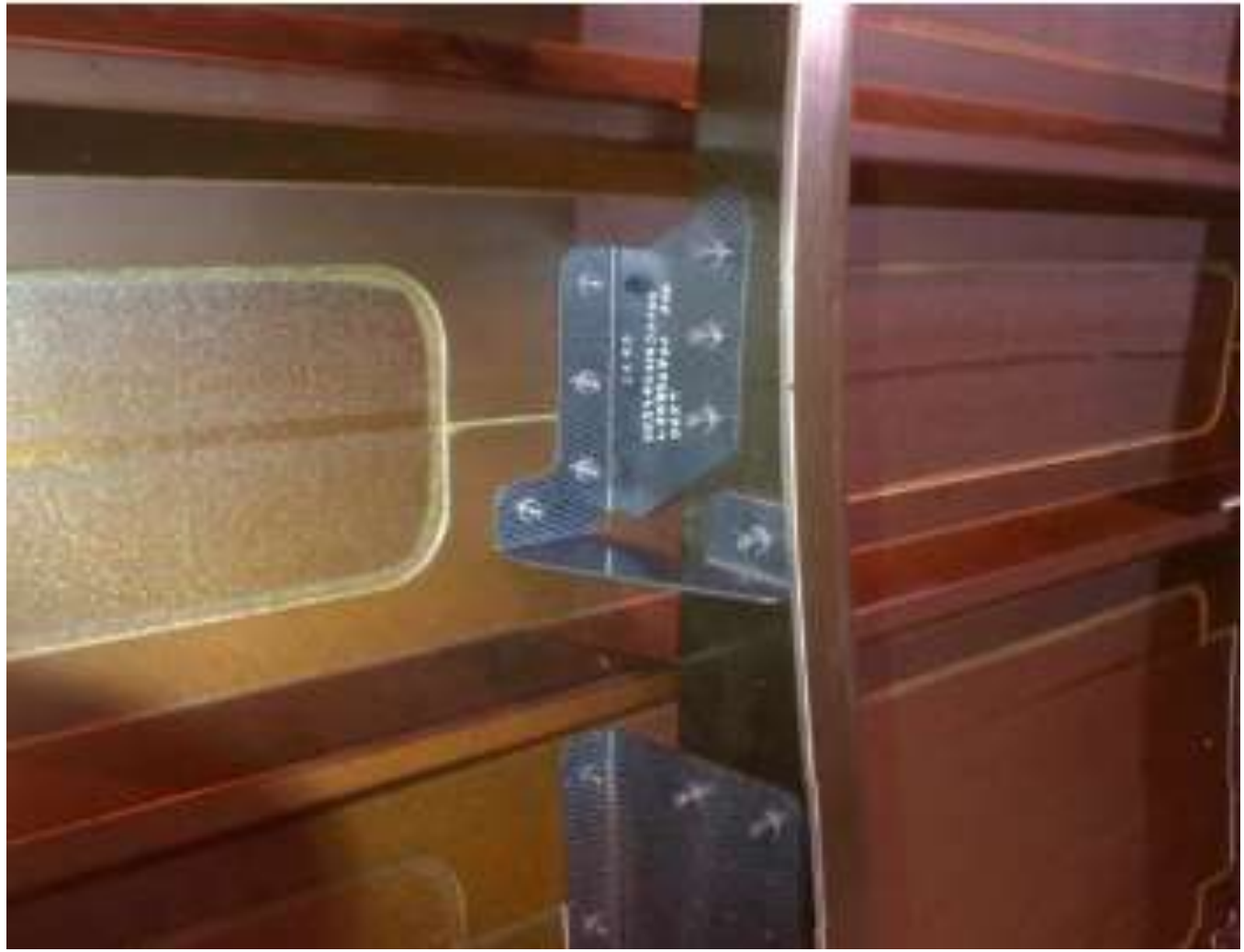
Source: Airbus

Thermoplastic Consolidated Laminates

Tenax® TPCL PEEK-HTA40 ON BOARD OF AIRBUS A350XWB

Source: Airbus

Thermoplastic Consolidated Laminates



Technology Readiness Level

Fabric prepreg and consolidated laminates:

- Tenax® TPCL PEEK-HTA40 and TPWF PEEK-HTA40:
  - TRL9
  - already aerospace qualified and used for flying components

Unidirectional tape:

- Tenax® TPUD PEEK-HTS45
  - TRL9 for industrial application
  - TRL 8 for aerospace application

Rodrigo Cesar Berardine
Sales and Marketing Manager
rberardine@tohotenax-us.com
+55 11 5070-3862
+55 11 98706-1766

Think ThermoPlastic.

Toho Tenax

Thanks for your attention – Questions ??????