Ultrablade® Fabrics – Reducing the cost of wind energy

OWENS CORNING Composite Solution Business

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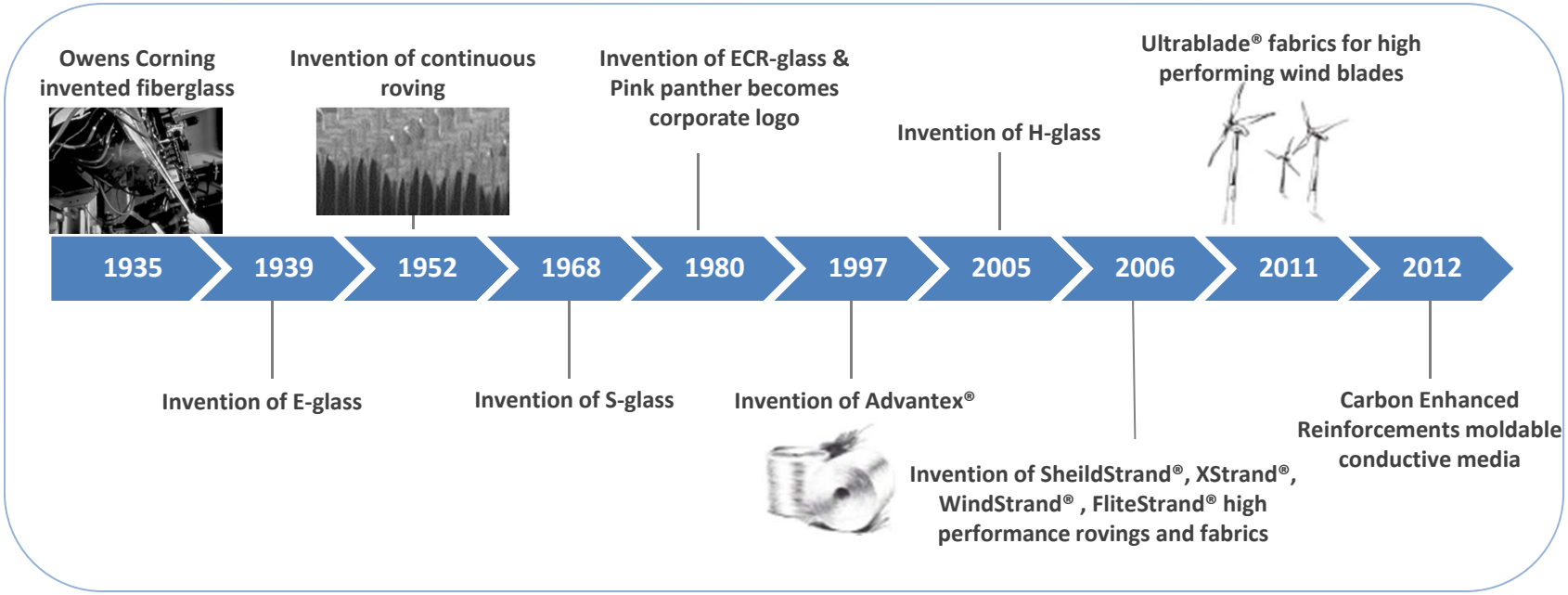
Leading fiberglass solutions with innovations for 80 years

Founded in 1938, a global industry leader in glass fiber insulation, roofing, asphalt, and glass fiber reinforcements with **sales of $4.8 billion in 2011**.

16,000 employees in 28 countries.

FORTUNE 500 company for **56 consecutive years**

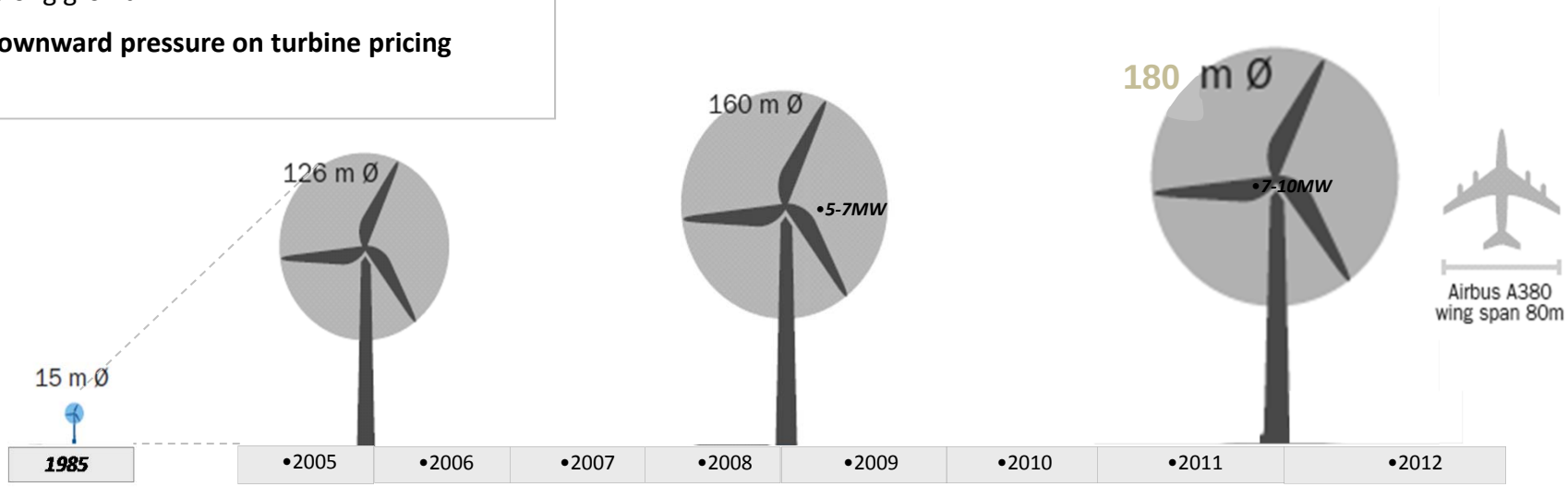
Global leader in glass fiber for composites with **37 plants in 15 countries**



Trends in Wind Energy

Predicted Trends for next 5 yrs.*

- Strong growth
- **Downward pressure on turbine pricing**



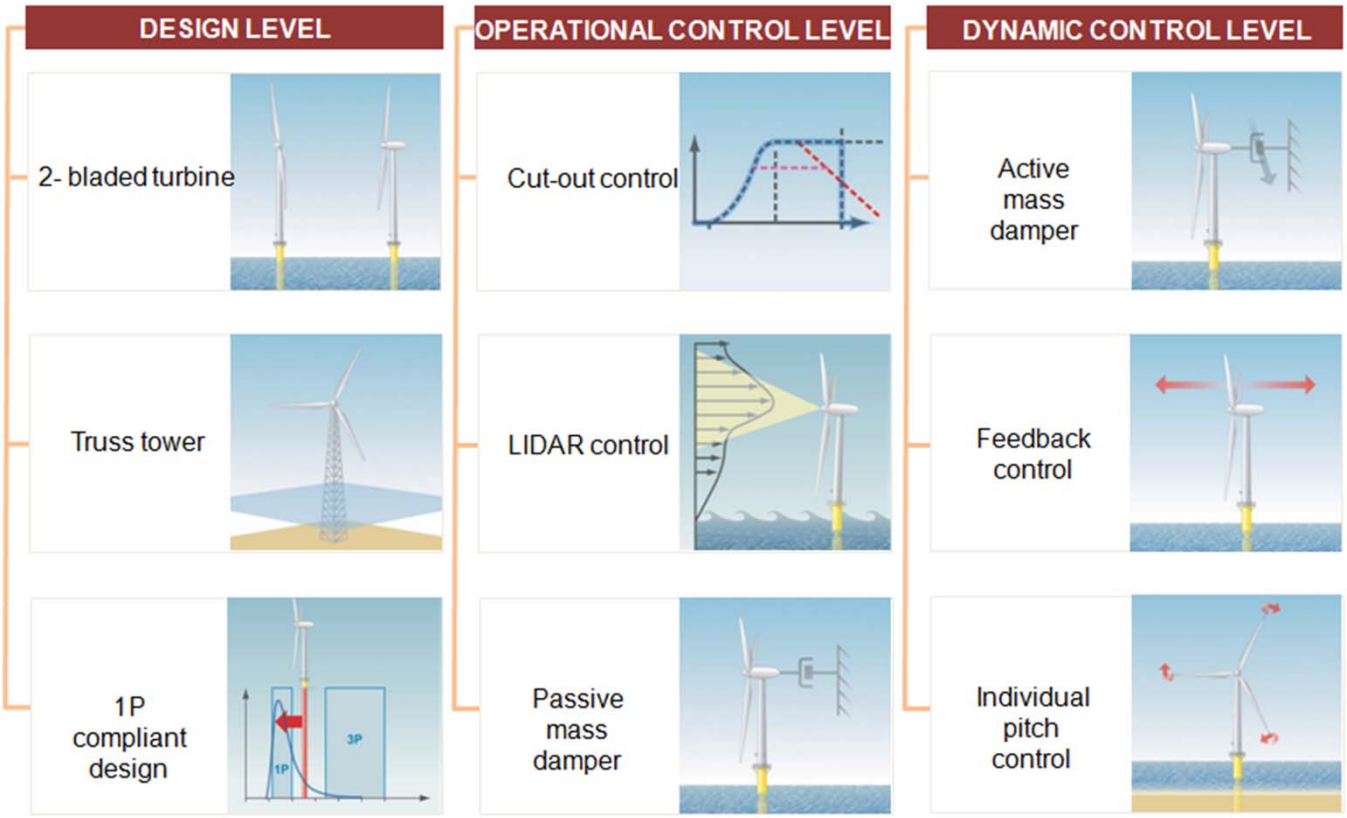
Technology Trends → **Turbines are getting larger**

Technology Solutions → **Need longer, lighter & lower cost blades with longer life**

Requirement for longer, lighter & cost effective blades will drive innovation

•Emerging Energy Research, Report Commissioned by OC May 2010
• European Wind Energy Association Fact sheets 2010

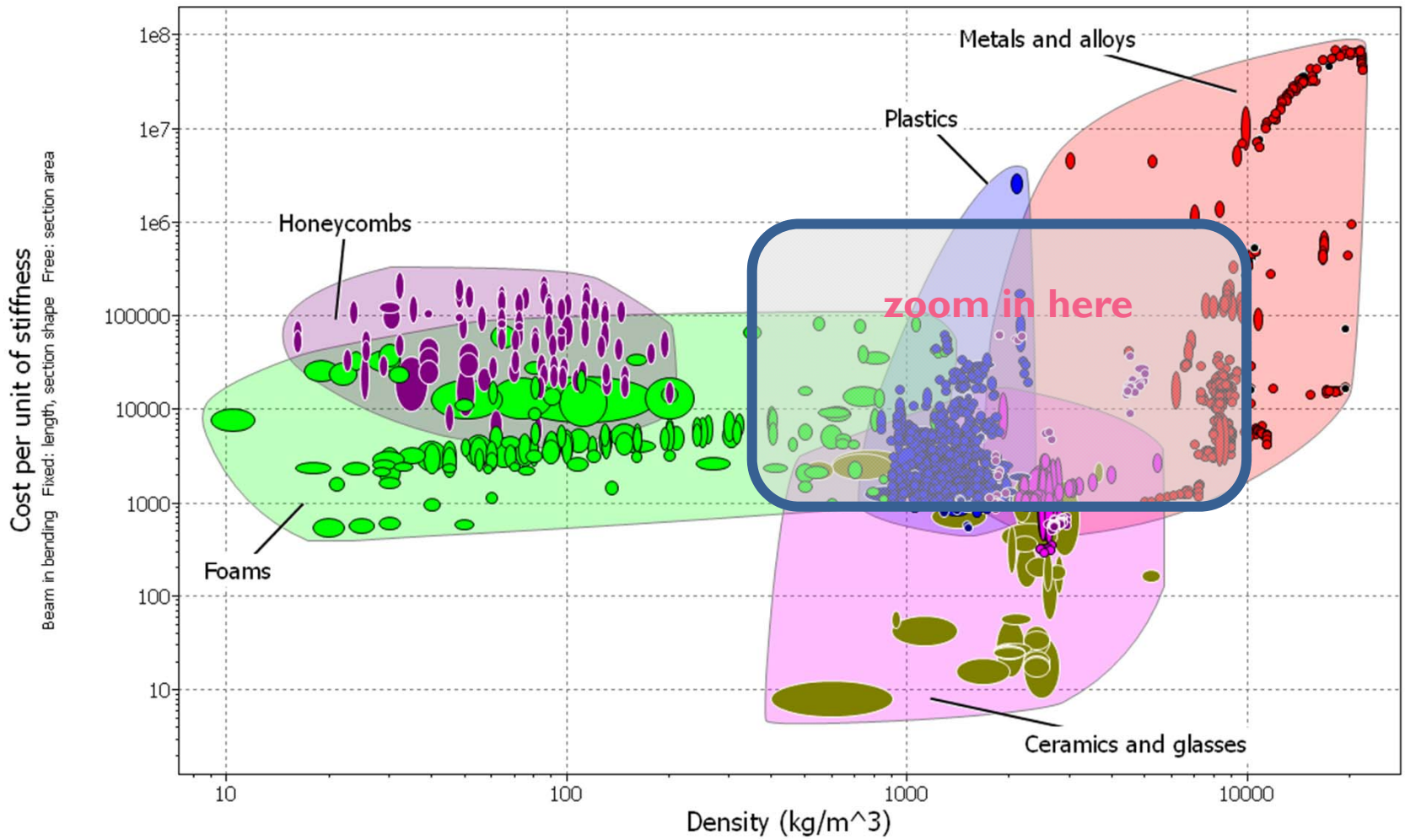
Technical Advancements for Reduced Cost of Energy



Source: Upwind Project, Public Report

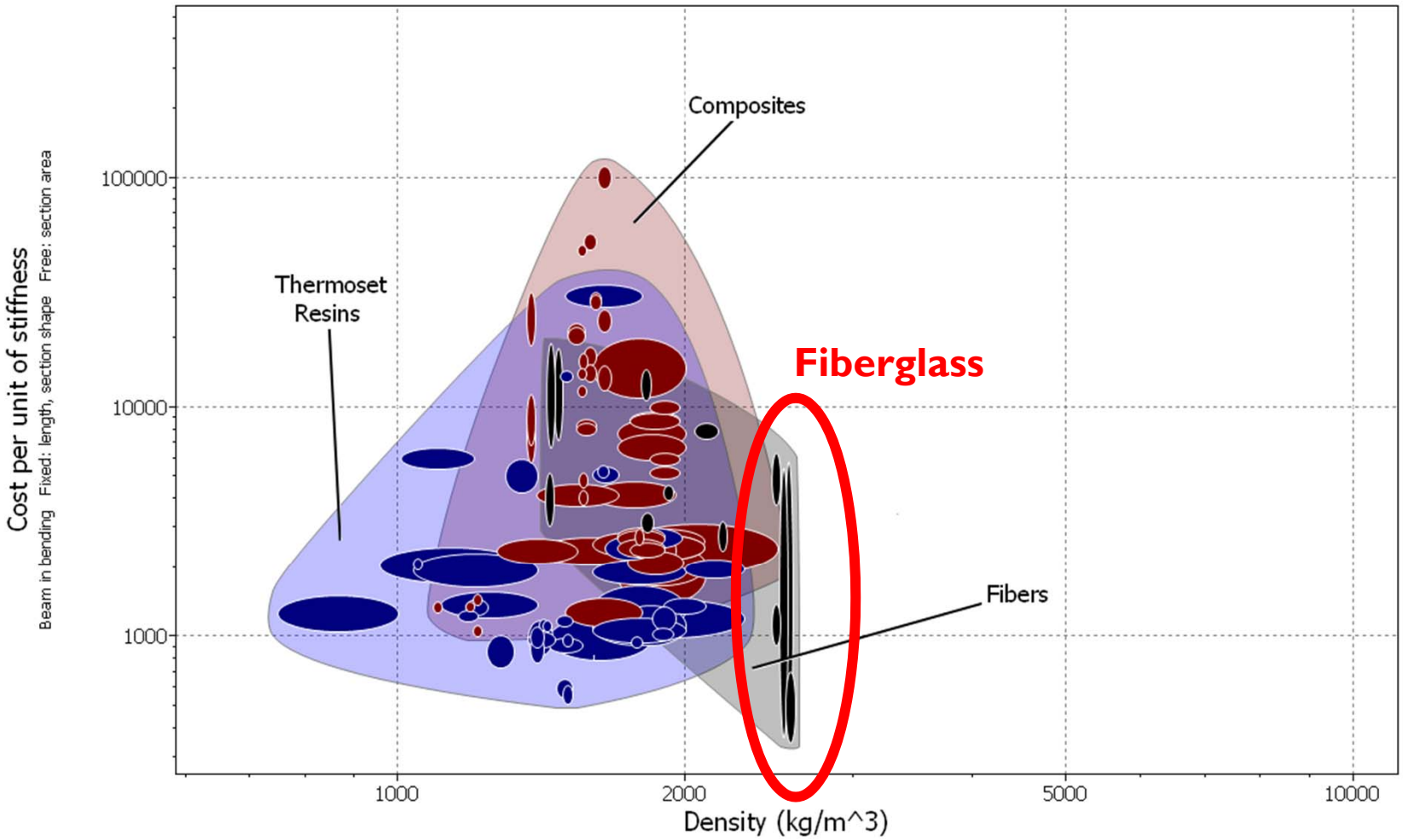
Material systems need to follow the trends to reduce the cost of wind energy

Blade Material Selection Based on Stiffness per $



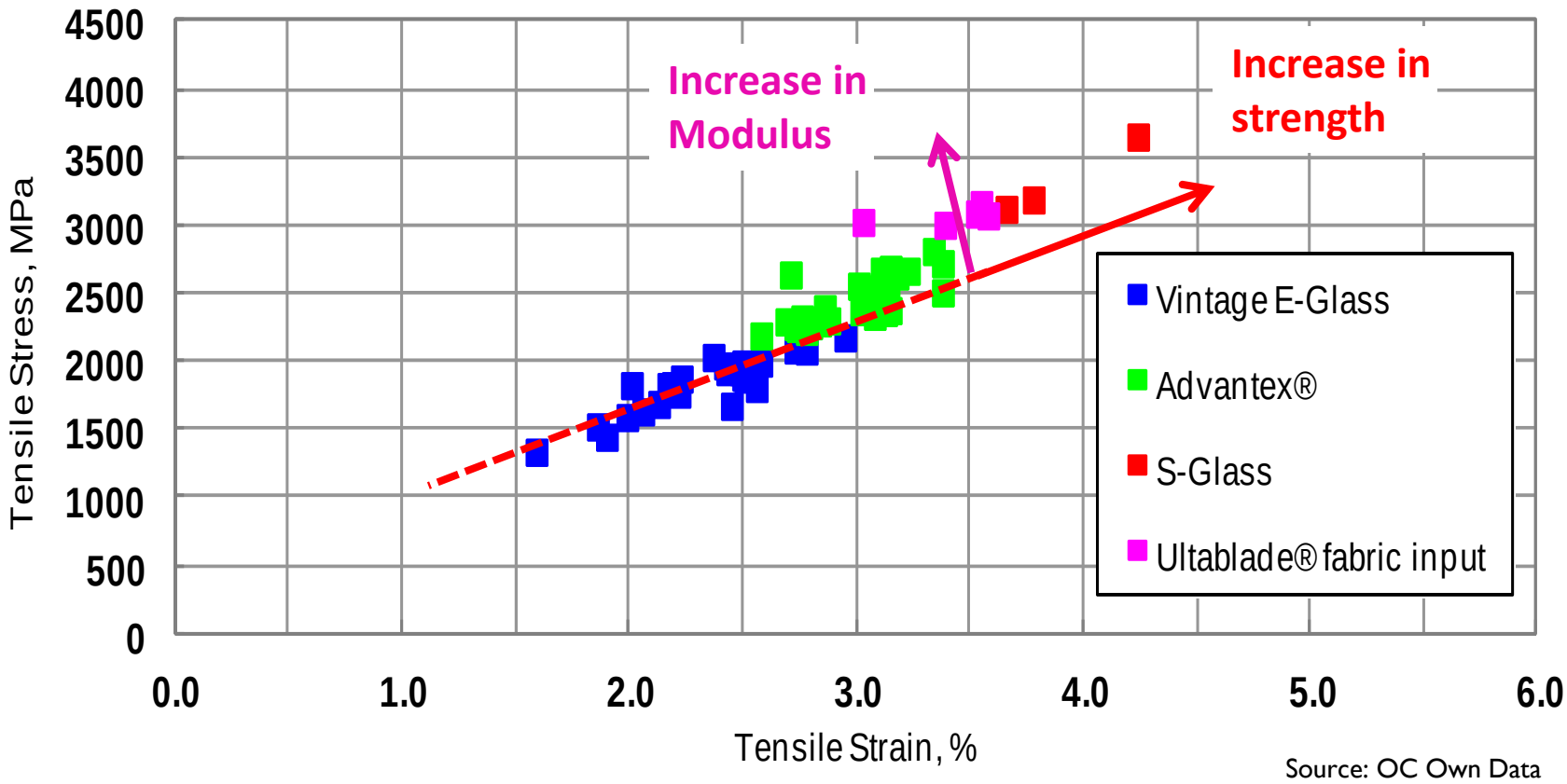
Composite materials offer the best balance of specific stiffness and density
They are light, strong and durable

Composite Material Choices to reduce Cost per Mw/h



Fiberglass reinforcement provides the cost advantage maintaining the composites advantage

Historical Evolution of Glass Fiber Properties



Source: OC Own Data

Optimizing the performance envelop for Wind Industry with higher modulus glass

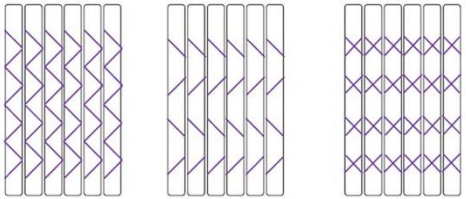
Measuring Glass Fiber Young's Modulus

$$V_{sound} = \sqrt{E\rho}$$

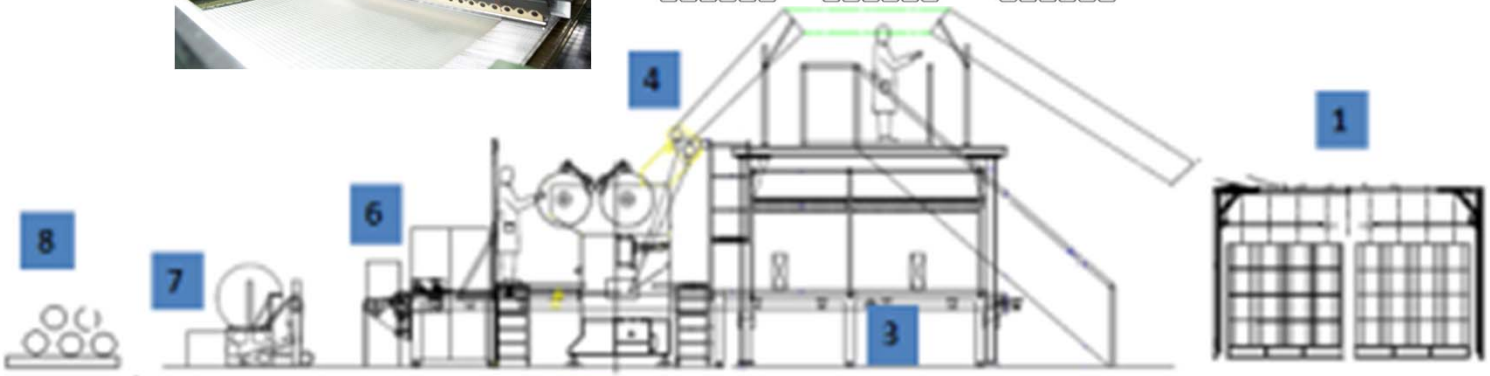
A repeatable, reliable method for glass fiber modulus measurement
ASTM C623-92: Young's Modulus..for…Glass and Glass-Ceramics by Resonance

Construction of the Leading UD fabrics for Blade Spar Caps

Typical Stitching patterns



Stitching Technology
-Yarn Denier
-Pattern
-Tension, etc



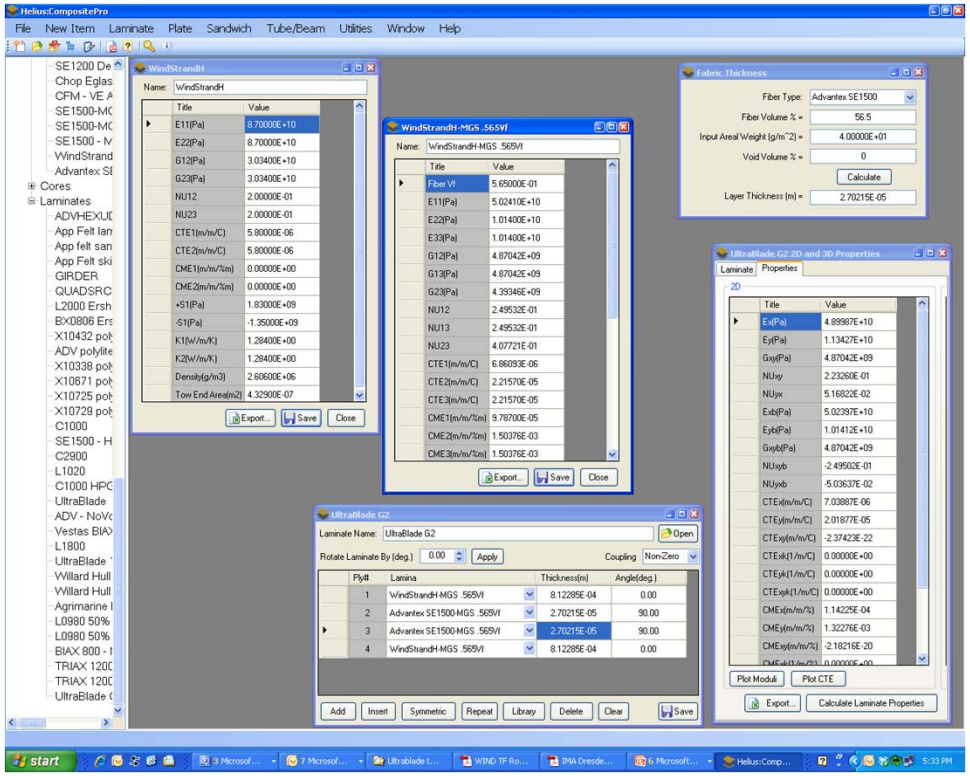
Warp constructions
-Glass
-Micronage
-Tension etc

Winding Process

Every UD fabric manufacturing process step is critical can affect the overall performance

Comparison of Theoretical and Measured Ultrablade® Modulus at 56% Vf

CompositePro using Sonic Modulus



Ex = 49 GPa

IMA Test Lab

Test Report

LTx1240 static characterisation

Test Report No.: B440/10.1

IMA DRESDEN

4 Evaluation

4.1 Fibre content according to DIN EN ISO 1172

Table 6: Fibre content of test laminate B440/10-UD1

Specimen-no.	l [mm]	b [mm]	a [mm]	ρ_L [g/cm³]	ψ [g/m²]	W_f [%]	V_f [%]	V_0 [%]
B440/10-UD1-FC11	30,01	19,96	1,75	1,968	2556	75,00	56,55	1,76
B440/10-UD1-FC12	30,04	20,03	1,74	1,964	2524	74,94	56,39	1,90
B440/10-UD1-FC13	30,00	20,02	1,78	1,969	2565	75,11	56,66	1,80
Average value:				**1,967**	**2548**	**75,02**	**56,54**	**1,82**
Standard deviation:				**0,003**	**21,8**	**0,09**		
Coefficient of variation:				**0,13%**	**0,86%**	**0,12%**		

IMA DRESDEN

4.3 Compression test according to DIN EN ISO 14126

Table 12: Compression test in 0°test direction acc. to DIN EN ISO 14126, test series B440/10-UD1-C0

Specimen-no.	a [mm]	b [mm]	F_m [N]	σ_{cm} [MPa]	E_c [GPa]	ε_{cm} [%]	Validity $\Delta\varepsilon_c$ [%] 10% F_m	90% F_m	Failure mode
B440/10-UD1-C0-01	1,71	14,96	22490	879,1	49,948	1,97	0,903	1,184	2
B440/10-UD1-C0-02	1,71	14,88	25702	1010,1	49,822	2,09	0,023	1,264	2
B440/10-UD1-C0-03	1,70	14,91	25319	998,9	50,742	2,06	1,900	3,044	2
B440/10-UD1-C0-04	1,70	14,92	22408	883,5	51,028	1,77	1,905	4,441	2
B440/10-UD1-C0-05	1,71	14,90	22834	896,2	50,569	1,83	1,177	0,440	2
B440/10-UD1-C0-06	1,71	14,91	21478	842,4	50,300	1,70	1,247	0,251	2
B440/10-UD1-C0-07	1,72	14,95	21515	836,7	49,576	1,71	0,037	0,005	2
Average value:				**906,7**	**50,284**	**1,87**			
Standard deviation:				**70,3**	**0,528**	**0,16**			
Coefficient of variation:				**7,8%**	**1,0%**	**8,6%**			
Max:				**1010,1**	**51,028**	**2,09**			
Min:				**836,7**	**49,576**	**1,70**			
R(5%,95%,υ,n):				**747,4**	**49,087**	**1,51**			

Test Report

LTx1240 static charac

Test Report No.: B44

4.2 Tensile test ac

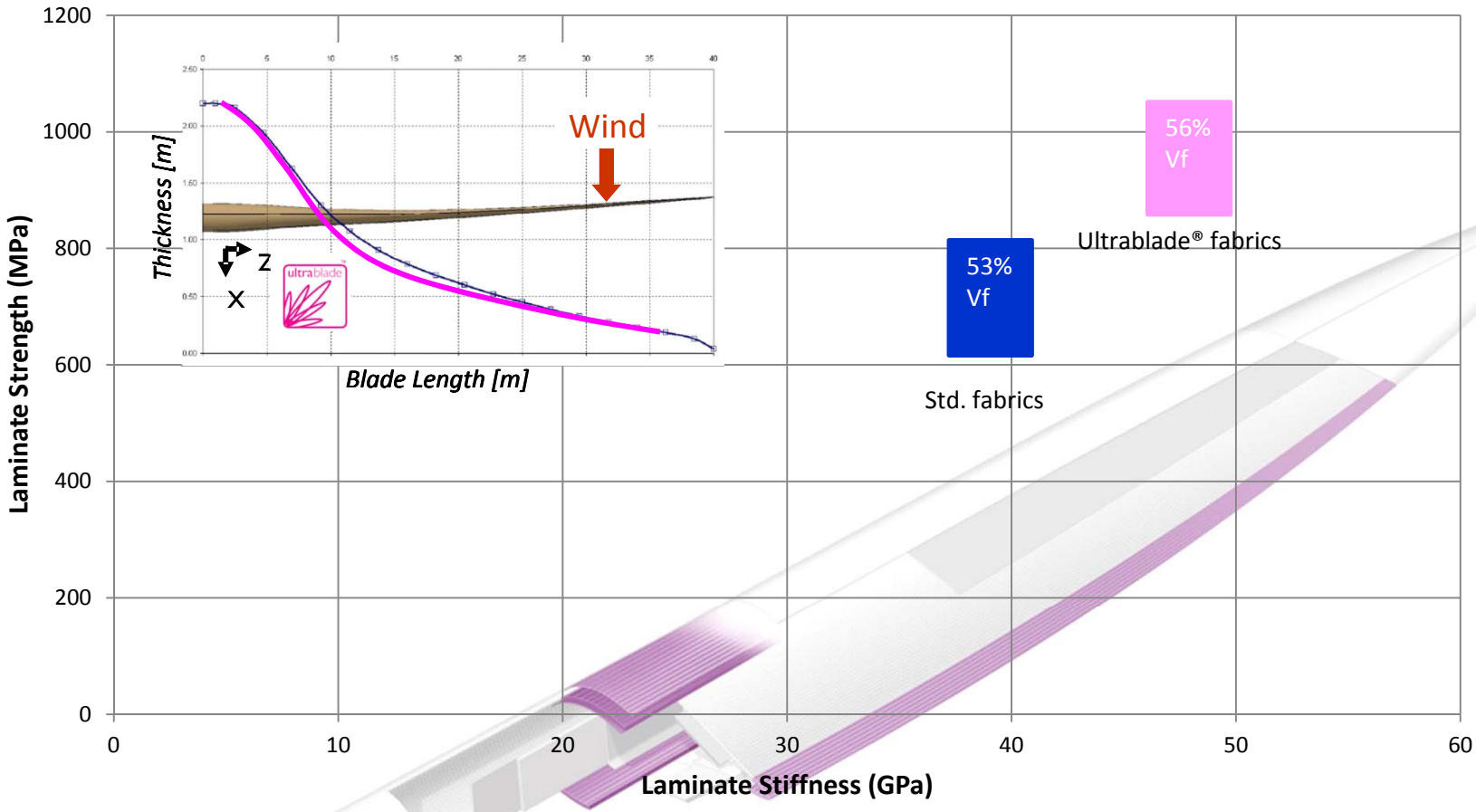
Table 10: Tensile test i

Specimen-no.	a [mm]	b [mm]	F_m [N]	σ_m [MPa]	E [GPa]	ε_m [%]	μ [-]
B440/10-UD1-T0-1	1,76	15,03	29445	1113,1	51,472	2,45	0,36
B440/10-UD1-T0-2	1,79	15,00	29046	1081,8	49,674	2,53	0,38
B440/10-UD1-T0-3	1,75	15,02	28653	1090,1	48,149	2,61	0,28
B440/10-UD1-T0-4	1,78	14,99	27804	1042,0	45,710	2,38	0,30
B440/10-UD1-T0-5	1,79	14,97	26717	997,0	48,047	2,44	0,39
B440/10-UD1-T0-6	1,76	14,90	28091	1071,2	49,292	2,47	0,30
Average value:				**1065,9**	**48,724**	**2,48**	**0,34**
Standard deviation:				**41,0**	**1,931**	**0,08**	**0,05**
Coefficient of variation:				**3,8%**	**4,0%**	**3,1%**	**14,3%**
Max:				**1113,1**	**51,472**	**2,61**	**0,39**
Min:				**997,0**	**45,710**	**2,38**	**0,28**
R(5%,95%,υ,n):				**970,9**	**44,250**	**2,30**	**0,23**

Average Et&Ec = 49.5 GPa

Excellent agreement between Classic Laminate Theory using Sonic Modulus values and actual test data

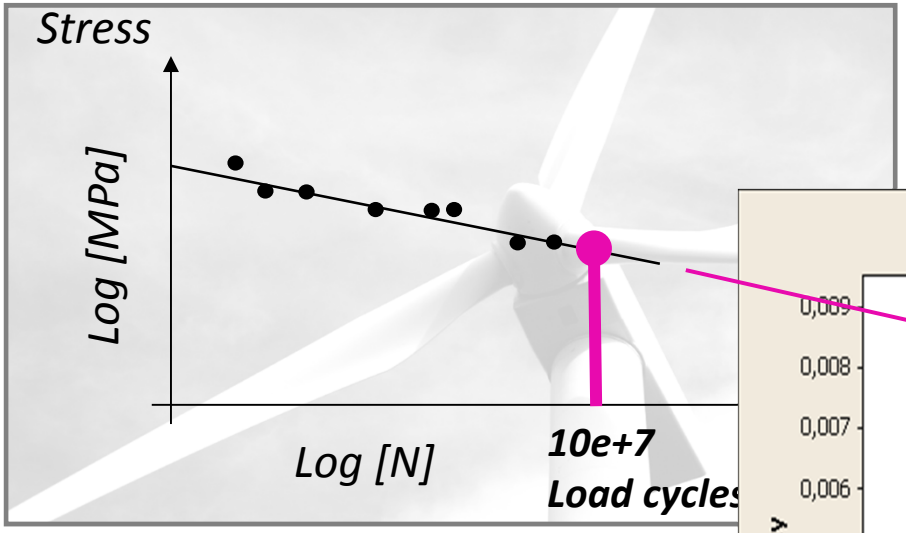
Higher performance of Ultrablade® Fabrics



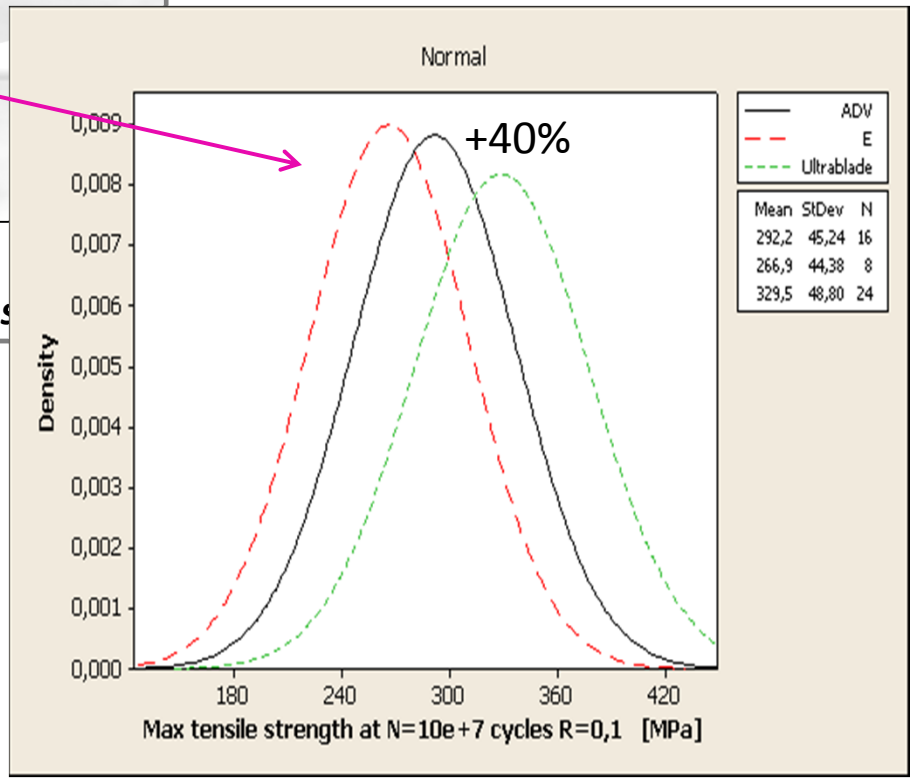
Ultrablade® fabrics provide significant improvement in modulus, strength and increased fiber volume fraction in UD fabric laminates

Source: Own Data, Optimat, Independent test reports

Superior Fatigue Performance of Ultrablade® Fabrics



R=0,1
(high tension – low tension)



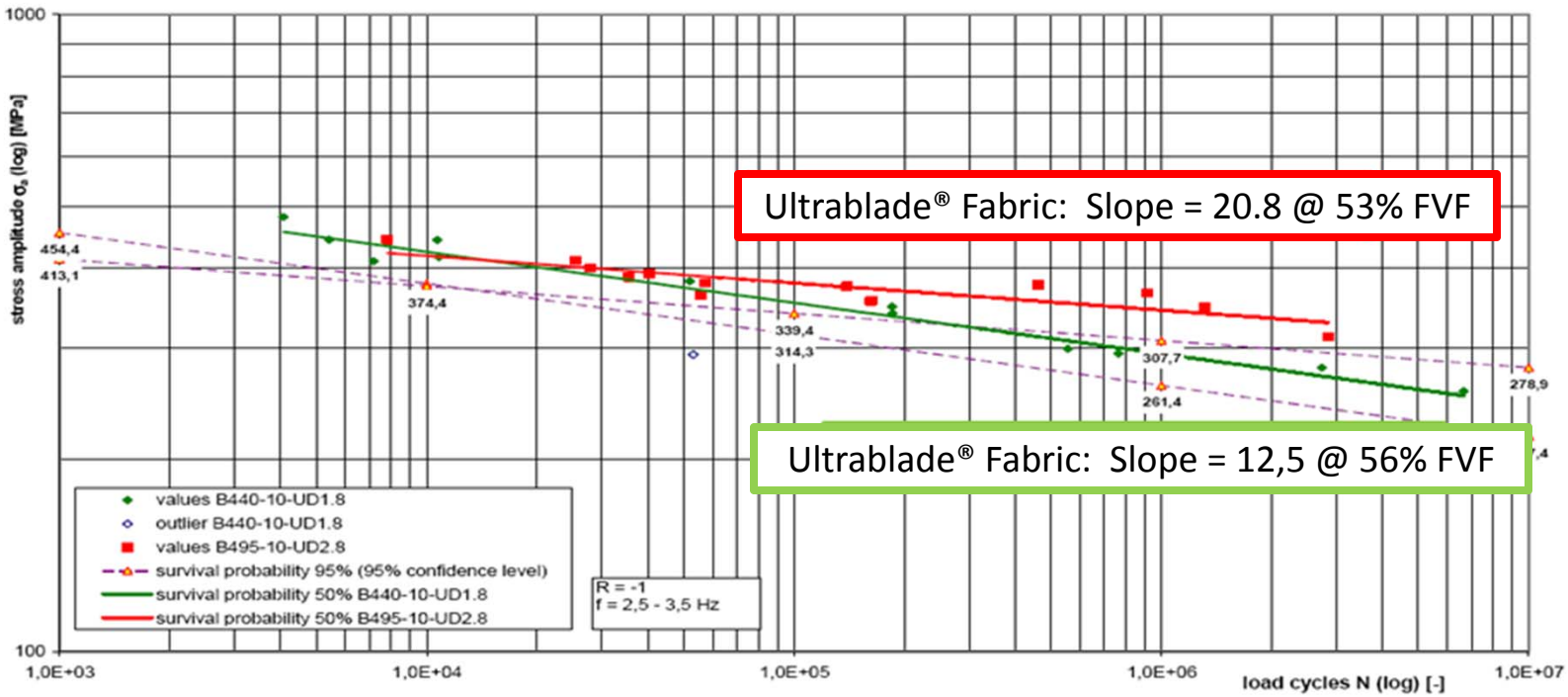
After analyzing multiple fatigue series the allowable maximum strength has been observed at +40% vs E-glass fabrics

Source: Own Data

Ultrablade® has better fatigue performance vs E-glass

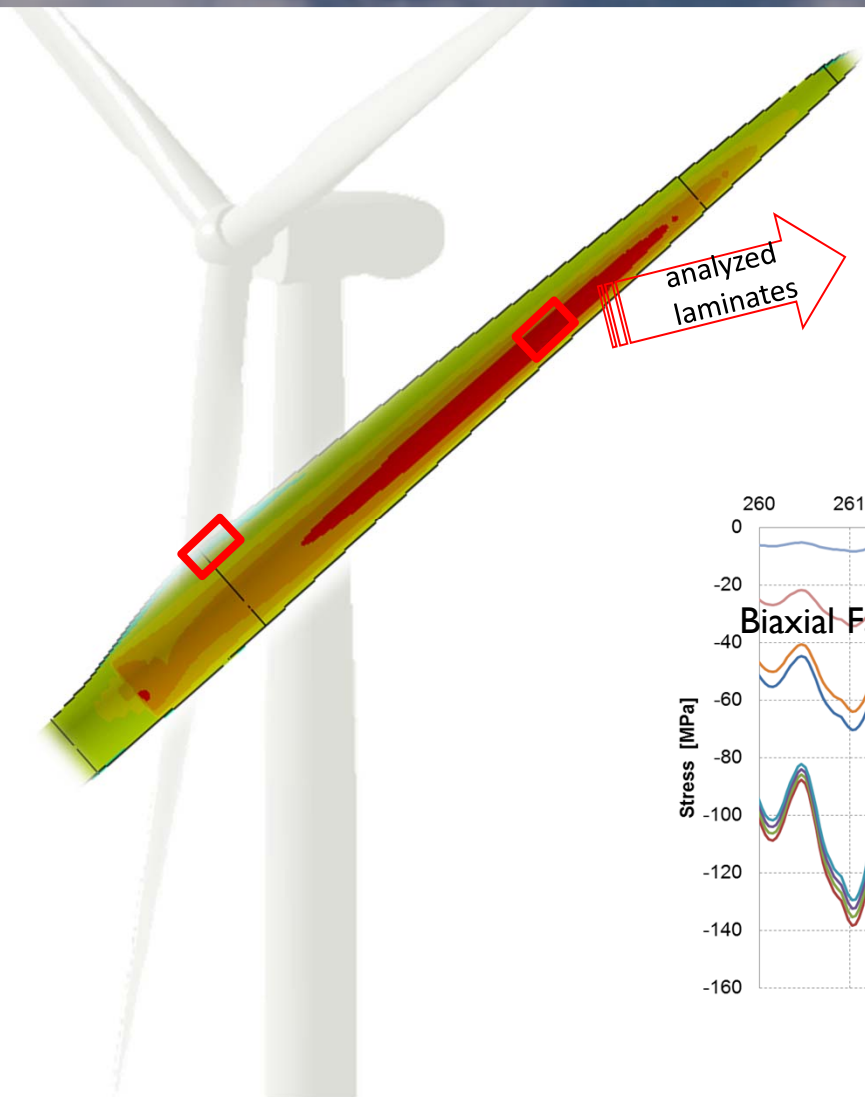
Ultrablade® Exceeds GL Fatigue Requirements

- Ultrablade Fabrics exceed GL blade design minimum fatigue slope requirement
  - GL requires a minimum slope of 10
  - Ultrablade has slope of 12.5 and 20.8

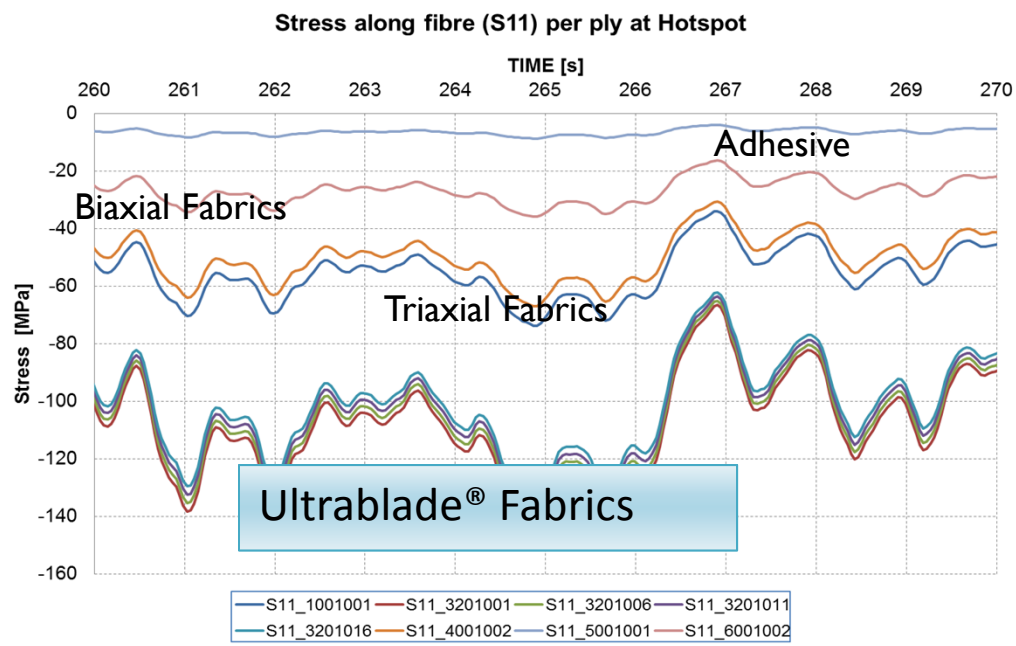


Ultrablade® gives excellent fatigue results even at higher fiber volumes

Modeling the fatigue performance of Ultrablade® Fabric



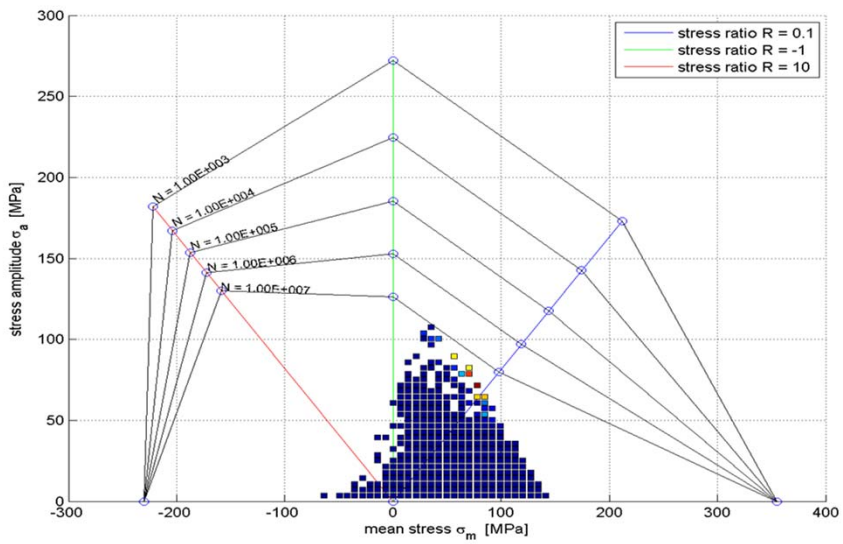
1001001	1002001	2 PLIES OF TRIAX
1001002	1002002	
3201001	3202001	16 PLIES OF UD
3201002	3202002	
...	...	
3201015	3202015	
3201016	3202016	
4001001	4002001	2 PLIES OF TRIAX
4001002	4002002	
5001001	5002001	1 PLY OF ADHESIVE
6001001	6002001	2 PLIES OF PM45
6001002	6002002	
Extrados El. 214672	Intrados El. 314652	



Identified the fatigue hot-spot for a typical wind blade

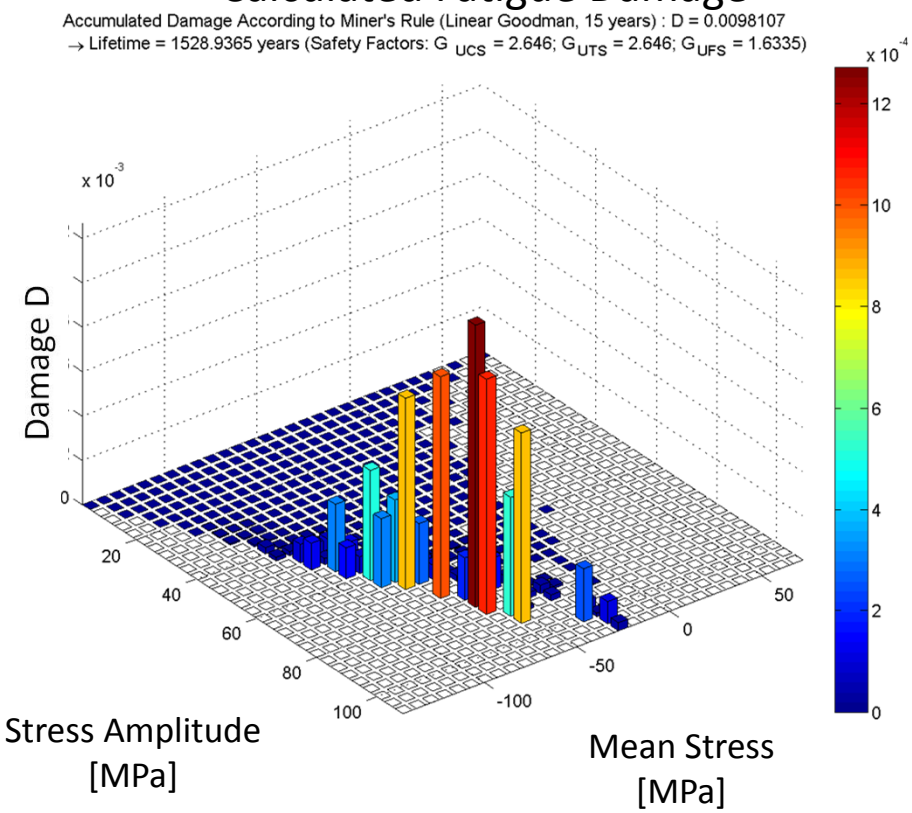
Calculated Fatigue Damage

Goodman Diagram up to $2*10^6$ cycles



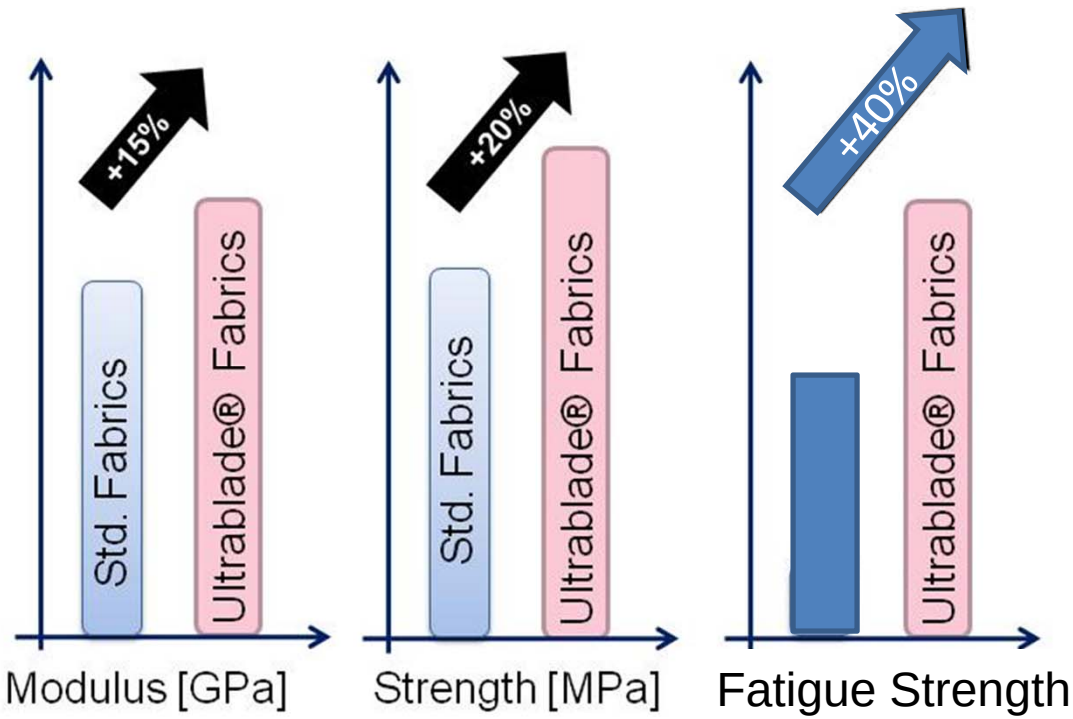
Goodman Diagram & Rain flow counting results

Calculated Fatigue Damage



Optimized blade design with weight reduction and improved laminate properties results in improved fatigue life

Ultrablade® Fabrics enable cost reduction of wind energy



Ultrablade® Fabrics - improved properties enables blade weight reduction & load reduction on other wind turbine's components such as pitch bearing, main bearing, main shaft & gear box

Higher Modulus, Strength, and Longer Blade Life Reduces Cost of Energy

Owens Corning

#1 supplier to wind industry with a full range of blade reinforcements

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