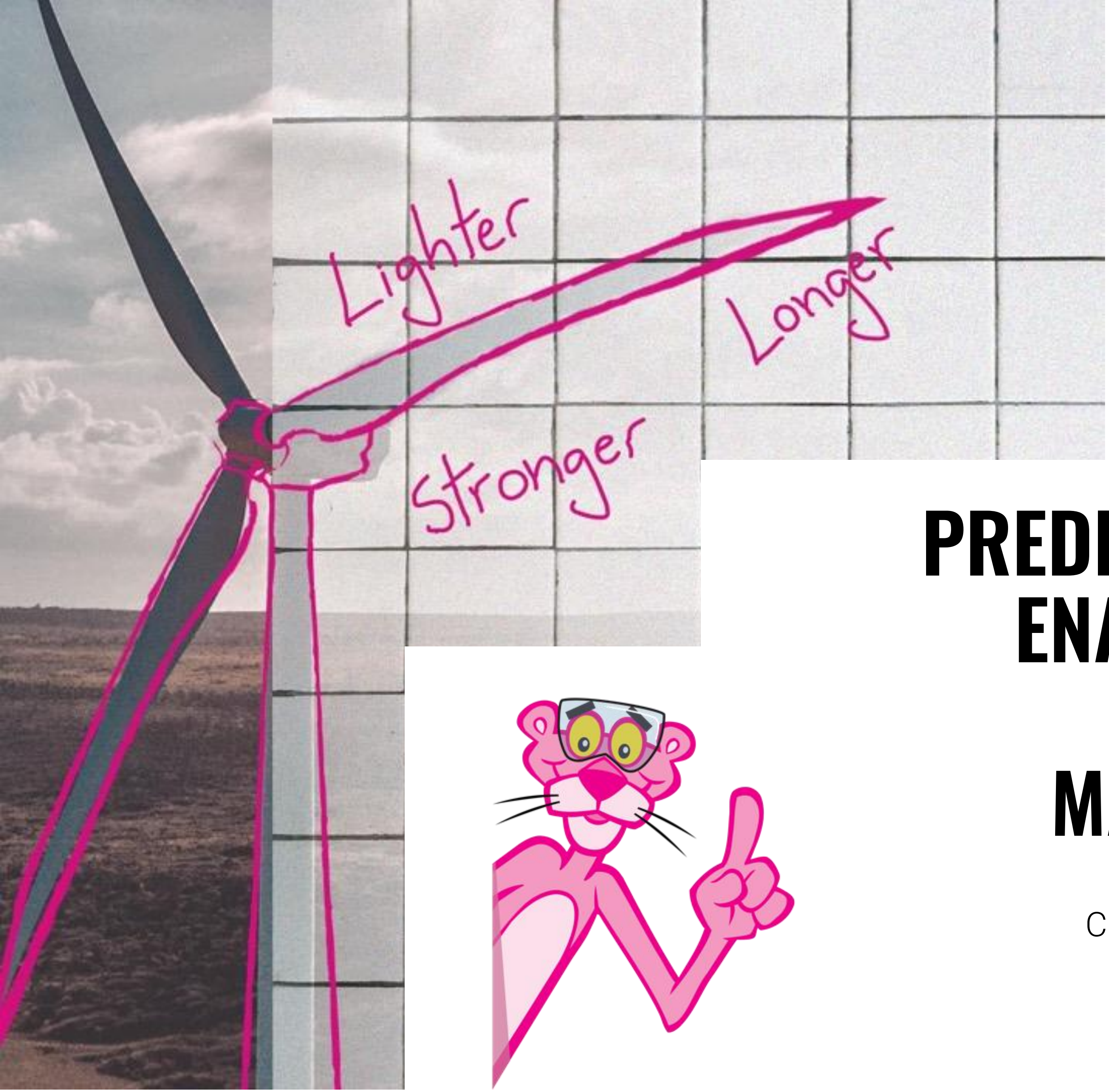


PREDICTIVE ANALYTICS ENABLING FOR HIGH PERFORMANCE MATERIALS DESIGN

Case Study: Wind | USTV January 2024

Dr. Anne Berthereau

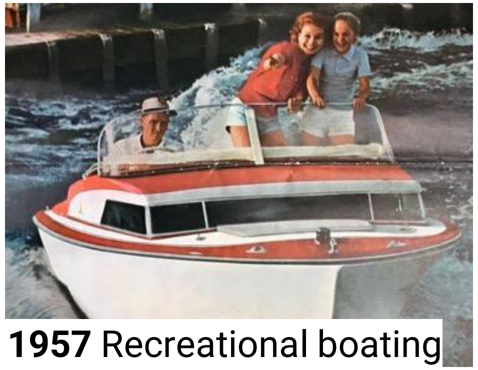
WHO IS OWENS CORNING?

1938 First Board of Directors

1939 World's Fair

1953 Chevrolet Corvette

1956 The color PINK



1957 Recreational boating

1969 Space suits

1975 Trans-Alaska Pipeline

1980 The Pink Panther™

1981 Hajj airport terminal

2005 Wind H glass

2008 Bird stadium

2018 PAROC

2022 Pinkbar

2022 OC Lumber

OWENS CORNING AT A GLANCE

OUR MISSION: TO BUILD A SUSTAINABLE FUTURE THROUGH MATERIAL INNOVATION

COMPANY OVERVIEW

19,000
Employees

100+
Manufacturing sites

31
Countries

~63%
Revenue from products that help customers save energy and avoid emissions[1]

54
New or refreshed product launches in 2022

OUR PURPOSE
Our people and products make the world a better place

OUR VALUES
Global in scope, human in scale

Caring | Collaborative
Curious | Committed

2022 FINANCIAL HIGHLIGHTS

$9.8B
Revenue

$1.8B
Adj. EBIT

$2.3B
Adj. EBITDA

18%
Adj. EBIT as % of net sales

23%
Adj. EBITDA as % of net sales

$12.88
Adj Diluted EPS

$1.3B
FCF

104%
FCF Conversion

71%
FCF returned to shareholders

REVENUE BY…

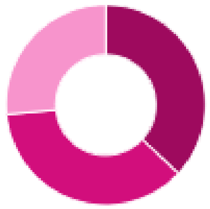
End market

Residential Construction Materials	59%
Commercial and Other Construction Materials	25%
Industrial and Other	16%

Geography

U.S.	70%
Europe	15%
Rest of World	8%
Asia Pacific	7%

Segment



Insulation	37%
Roofing	36%
Composites	27%

1. Owens Corning 2022 Sustainability Report, page 24

Note: Data as of 2022 Form 10-K; Consolidated figures eliminate intercompany net sales between reportable segments

Source: 2022 Form 10-K and Owens Corning management estimates; estimated error margin +/-5%

Please see Appendix C for the most comparable GAAP financial measure

GLASS FIBER MANUFACTURING

GLASS FABRIC TECHNOLOGIES

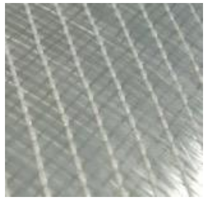
WHAT WE MAKE

Owens Corning products & applications

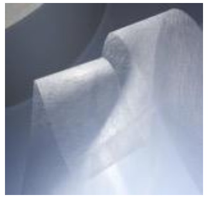
Fiberglas™ Rebar
Bridge construction, marine structures, tunnel boring/soft eye, rail, electrical isolation, historical preservation, architectural, balconies

WearDeck™ Decking
Commercial decking application and structural lumber for use in construction applications

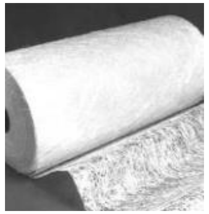
Ultraspar™ Pultrusions
High performance pultrusions for the wind energy market to enable longer blades



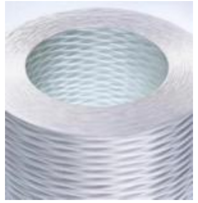
Knitted or woven fabrics
Wind, pipe, thermoplastic composites, industrial, recreational



Nonwoven veil
Construction, industrial, automotive, road paving



Chopped strand mat and continuous filament mat
Marine, transportation, recreation, corrosion resistance, construction



Continuous Fiber Type 30® single end roving
Chemical and sewage, oil, water processing (pipe and tanks), industrial (high-pressure vessels, pultruded items), wind energy, aerospace, ballistics, transportation (muffler filling), electrical (optical cable)

Continuous fiber multi-end roving
Construction (panels and translucent panels), corrosion resistant pipe and tanks, consumer (sanitary, recreational vehicles), transportation (headliner, body parts, semi-structural parts)

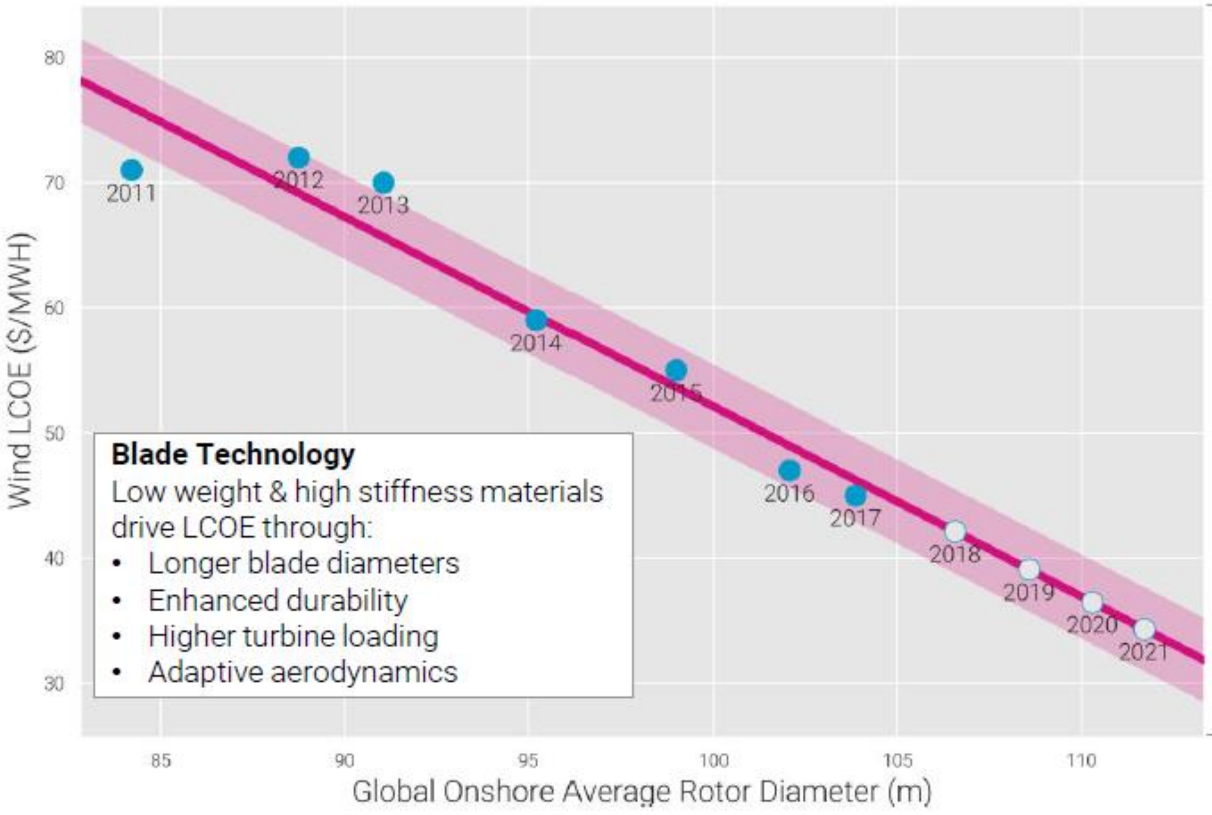
Chopped strand, wet-use
Building products (roofing and gypsum), industrial specialties

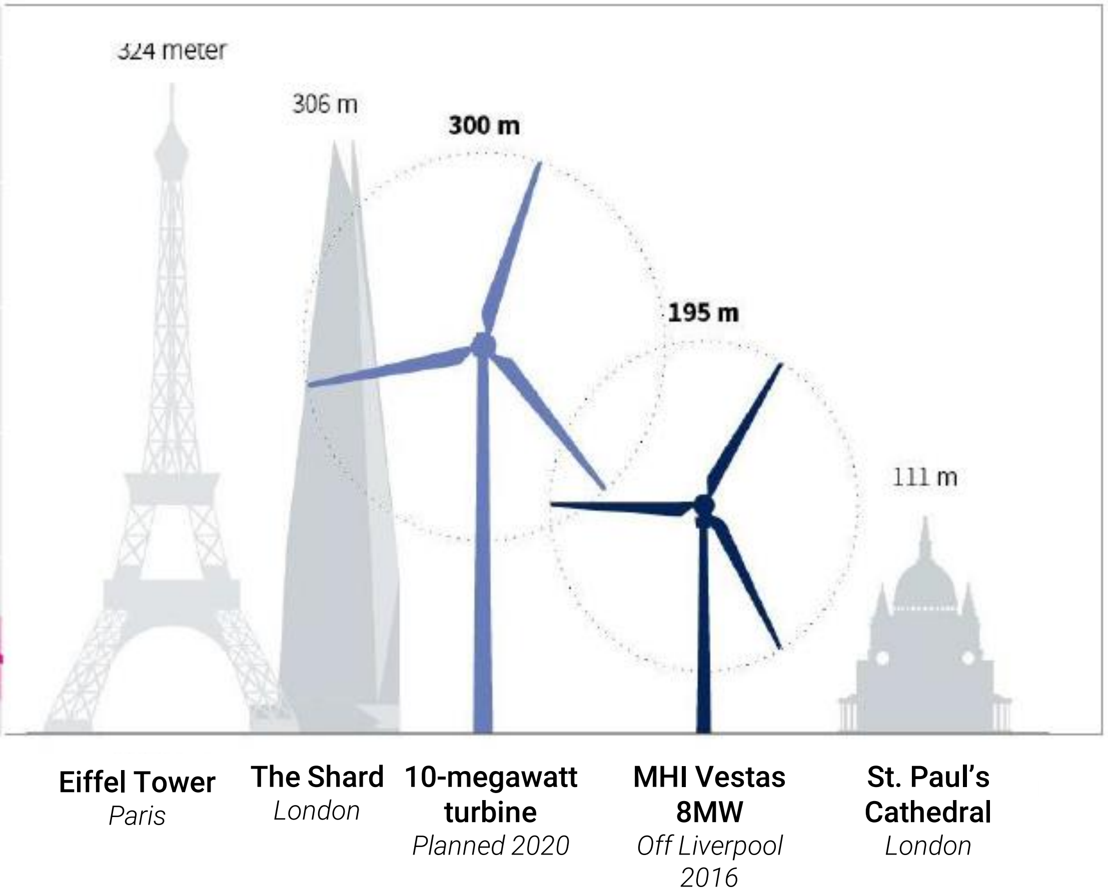
HOW DO WE INNOVATE?

OUR PRODUCTS* MAKE WIND ENERGY MORE COST EFFECTIVE

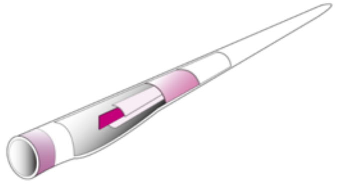
*Glass fabrics enable longer, stiffer, lighter wind blades year over year

BLADE TECHNOLOGY IS KEY IN DRIVING LCOE DOWN





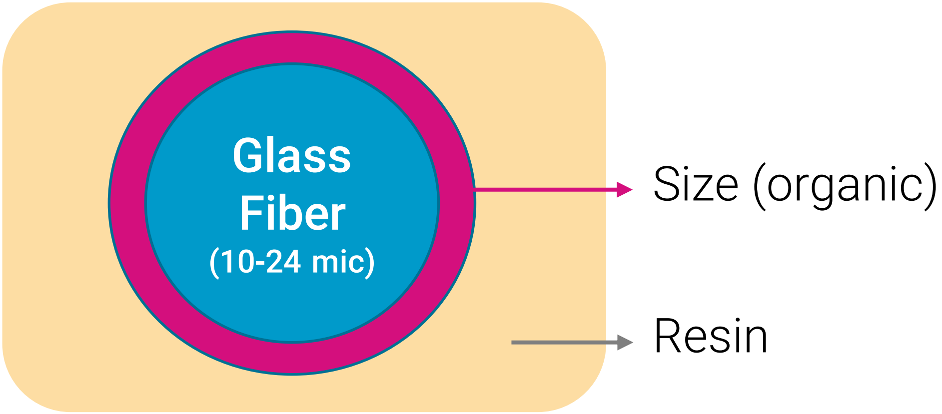
LCOE: Levelized Cost Of Energy
(measures Lifetime cost divided by energy production)



Source: Data source World Mackenzie Power & Renewables December 2018

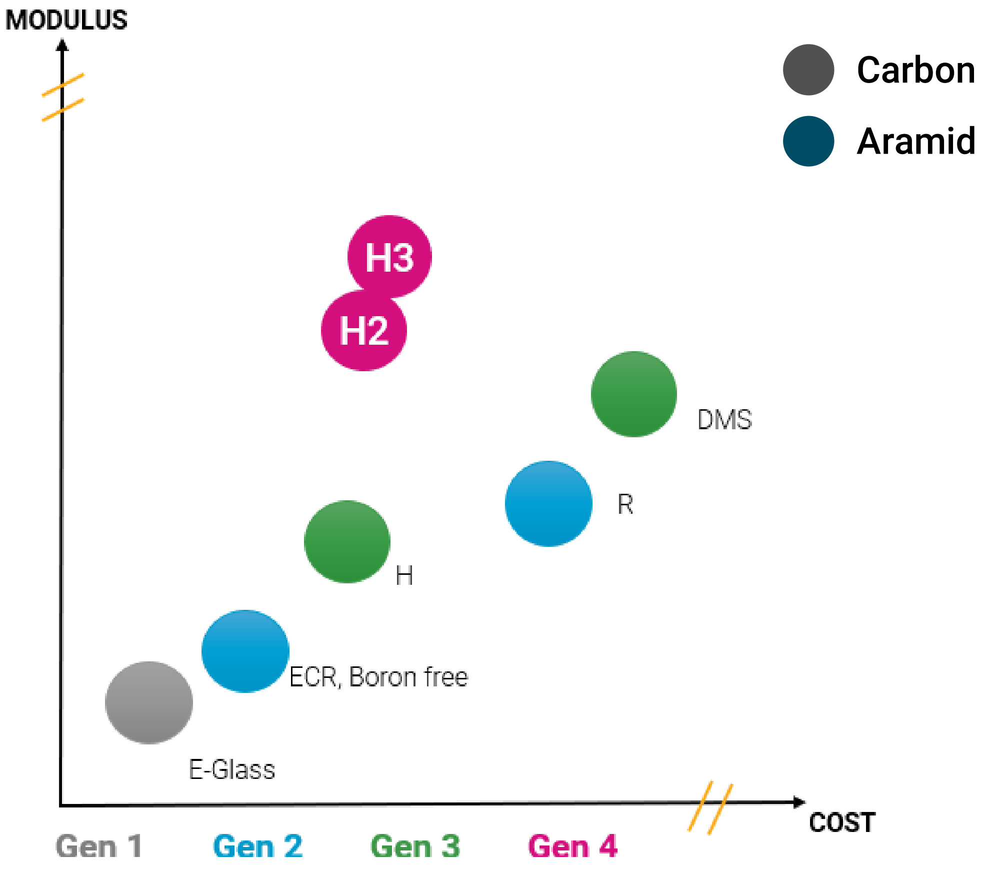
LONGER BLADES DESIGN REQUIRES:

- High glass modulus (Gpa > 90)
- Fatigue

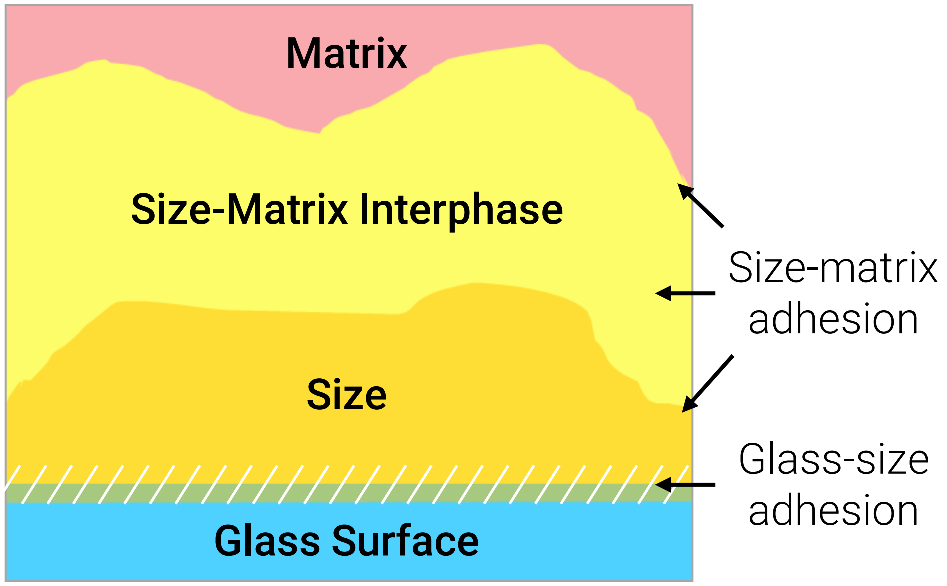


MATERIALS PROPERTIES

ENABLER YOUNG MODULUS => GLASS CHEMISTRY

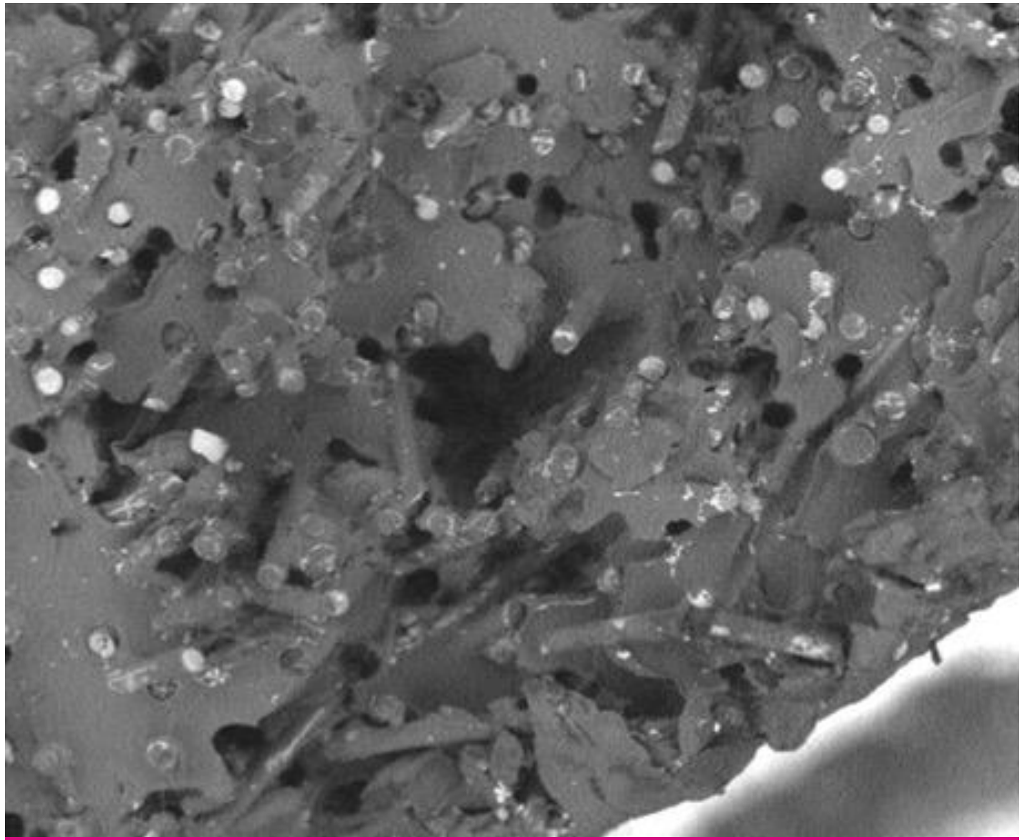


ENABLER FATIGUE => SIZE CHEMISTRY => INTERFACE VISCO ELASTIC PROPERTIES

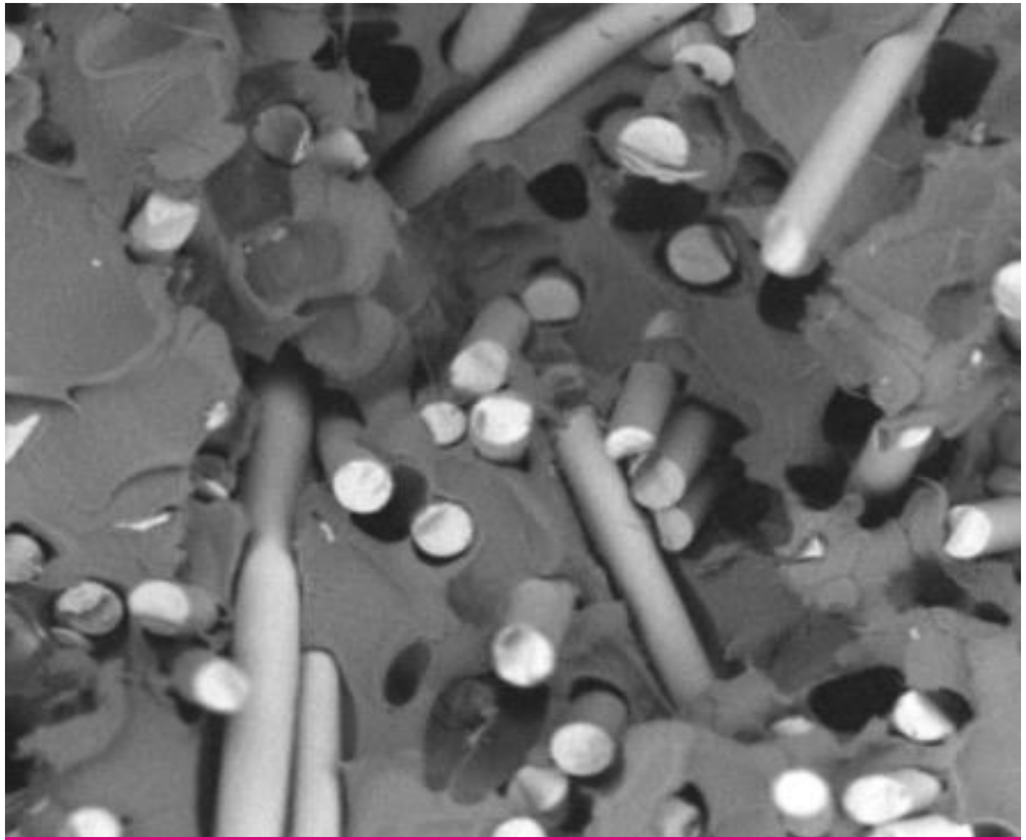


Challenge: test one size and related fatigue take **6 weeks**

INTERFACE LAMINATES



GOOD ADHESION



POOR ADHESION (DRY FIBER, UNCOVERED)

ASSUMPTIONS

Composites visco elastic properties are influenced by interphase viscoelastic properties & the adhesion quality between glass surface & resin.

OPPORTUNITIES

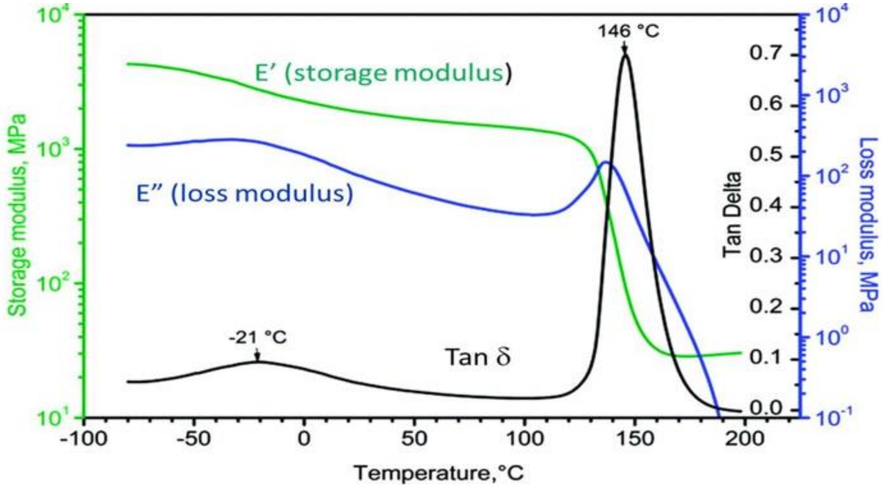
(1) Measurements **Fast & reliable** measurements of interface properties **(DMA)**

(2) Prediction

(3) Correlation interface properties with laminates fatigue performances

DMA parameters considered

- E” Loss modulus
- E’ Storage modulus
- Tan δ = (E”/E’)
- Temperature location of the Tan δ peak
- = (Tg of the composite material).
- Amplitude of the Tan δ peak



Typical DMA curve obtained for a viscoelastic material (polymers and polymer networks) where a secondary transition Tβ is observable (-21°C) on top of the primary transition Tα (146°C).

LITERATURE - Interface visco elastic properties measured by DMA

- Mäder & al: impact of glass fiber size on viscoelastic properties of epoxy UD
- Liao & al: established a correlation between static mechanical properties and Tanδ

(a) Silane coupling system

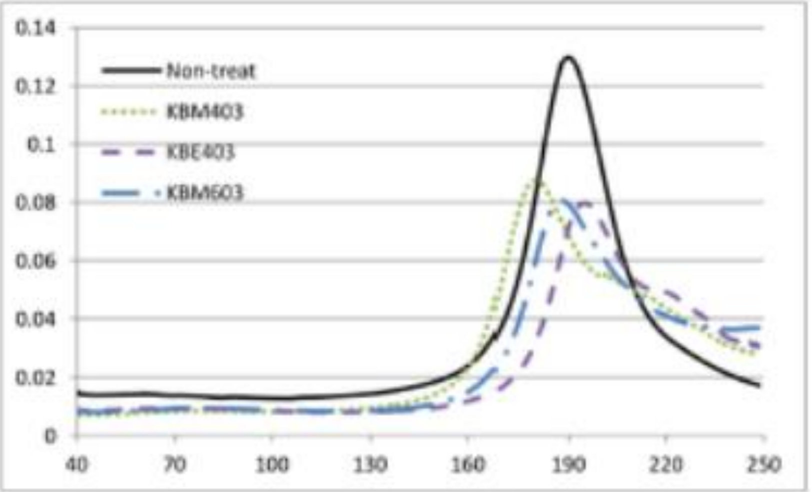


Figure 4-1: Impact of the silane type on the tan δ peak (position amplitude and shape).

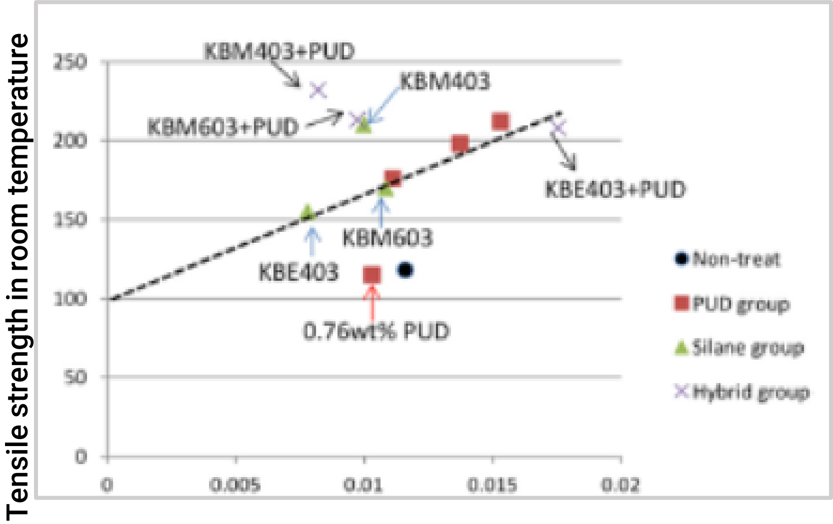
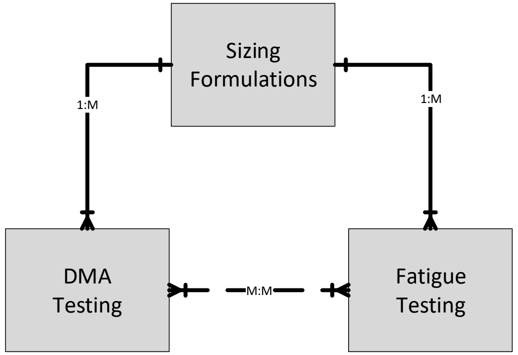


Figure 4-2: Correlation attempt between the viscoelastic properties and static mechanical properties of a composite.

Mäder & al « Static and Dynamic properties of single and multi-fiber epoxy composites modified by sizings » , Composites Science and Tcehnology 67 (2007) 1105-1115
Liao & al « Mechanical performances of glass woven fabrics composites: effect of different surface treatments agents « Composites: Part B 86 (2016) 17-26

(2) Owens Corning Linear & Quadratic Regression Models



Linear regression

$$Y_i = \beta_0 + \beta_1 X_{1,i} + \beta_2 X_{2,i} + \beta_3 X_{3,i} + \beta_4 X_{4,i} + \varepsilon_i$$

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.848(a)	.719	.607	33.535959

a. Predictors: (Constant), Î”T at h/2, E Glassy (T=), FWF (Panel average), Amplitude TanÎ´ peak

ANOVA(a)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	28827.513	4	7206.878	6.408	.008(b)
	Residual	11246.605	10	1124.661		
	Total	40074.118	14			

a. Dependent Variable: Result

b. Predictors: (Constant), Î”T at h/2, E Glassy (T=), FWF (Panel average), Amplitude TanÎ´ peak

Quadratic regression

$$Y_i = \beta_0 + \beta_1 X_{1,i} + \beta_2 X_{2,i} + \beta_3 X_{3,i} + \beta_4 X_{4,i} + \beta_{33} X_{3,i}^2 + \beta_{44} X_{4,i}^2 + \varepsilon_i$$

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.942(a)	.887	.803	23.739635

a. Predictors: (Constant), Î”T at h/2_SQ, E Glassy (T=), FWF (Panel average), Amplitude TanÎ´ peak_SQ, Amplitude TanÎ´ peak, Î”T at h/2

ANOVA(a)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	35565.556	6	5927.593	10.518	.002(b)
	Residual	4508.562	8	563.570		
	Total	40074.118	14			

a. Dependent Variable: Result

b. Predictors: (Constant), Î”T at h/2_SQ, E Glassy (T=), FWF (Panel average), Amplitude TanÎ´ peak_SQ, Amplitude TanÎ´ peak, Î”T at h/2

Yi : average fatigue for size i

4 independent variables

VARIABLES (IF QUESTIONS)

$$Y_i = \beta_0 + \beta_1 X_{1,i} + \beta_2 X_{2,i} + \beta_3 X_{3,i} + \beta_4 X_{4,i} + \varepsilon_i$$

Coefficient	Variable	Description
	Y_i	Average test result of the Endurance property, Fatigue, for sizing i
β_0		Intercept for the model
β_1	$X_{1,i}$	Panel average fiber weight fraction (FWF%) for the test panel for sizing i
β_2	$X_{2,i}$	Average test result of the E Glassy (T=) for sizing i
β_3	$X_{3,i}$	Average test result of the Amplitude of the Tanδ Peak for sizing i
β_4	$X_{4,i}$	Average test result of ΔT at Half Height of the peak for sizing i
	ε_i	Error for the regression equation for sizing i
	i	B2, …. , F

Table 8-3: Linear Regression Equation Results

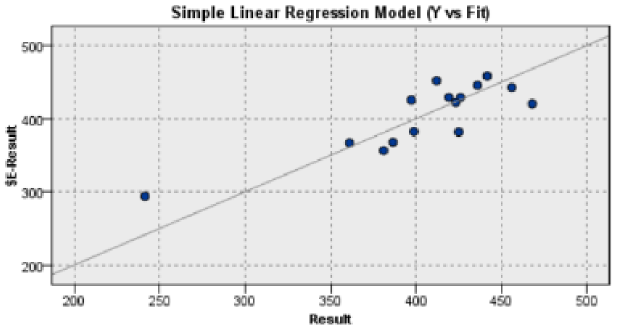
$$Y_i = \beta_0 + \beta_1 X_{1,i} + \beta_2 X_{2,i} + \beta_3 X_{3,i} + \beta_4 X_{4,i} + \beta_{33} X_{3,i}^2 + \beta_{44} X_{4,i}^2 + \varepsilon_i$$

Coefficient	Variable	Description
	Y_i	Average test result of the Endurance property, Fatigue, for sizing i
β_0		Intercept for the model
β_1	$X_{1,i}$	Panel average fiber weight fraction (FWF%) for the test panel for sizing i
β_2	$X_{2,i}$	Average test result of the E Glassy (T=) for sizing i
β_3	$X_{3,i}$	Average test result of the Amplitude of the Tanδ Peak for sizing i
β_4	$X_{4,i}$	Average test result of ΔT at Half Height of the peak for sizing i
β_{33}	$X_{3,i}^2$	Average test result of the squared Amplitude of the Tanδ Peak for sizing i
β_{44}	$X_{4,i}^2$	Average test result of the squared ΔT at Half Height of the peak for sizing i
	ε_i	Error for the regression equation for sizing i
	i	B2, …. , F

Table 8-6: Quadratic Regression Equation Results

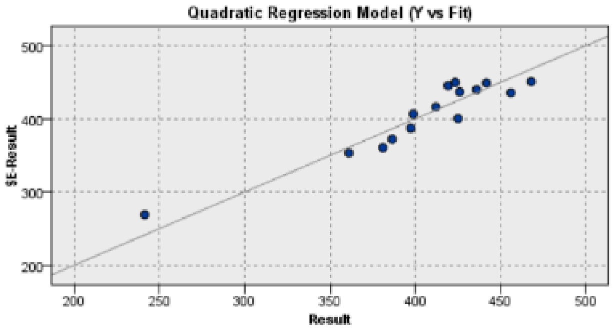
MODEL IMPROVMENTS FROM LINEAR TO QUADRATIC & ADV QUADRATIC

Linear



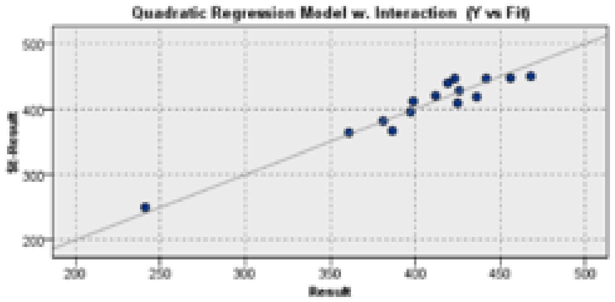
(R_a^2) **60%**

Quadratic



80%

Quadratic with interactions



86.7%

Quadratic model with one interaction (FWF*E) displays an very high R-squared 0,867

CONCLUSION

- Possible to correlate interface viscoelastic properties with fatigue composites performances

- **Measurements:** DMA + fatigue (ISO 13003:2003)

- **Optimal model:** quadratic with interaction

- **Benefit:** faster development time

THANKS!

LinkedIn | ANNE BERTHEREAU