

Innovative glass fibre developments aimed at improved composites properties for stronger and lighter wind turbine blades

Luc Peters, Yves Houet,
Dimitri Laurent, Willy Piret
and the 3B team

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Haus der Technik, Essen, Germany

- ❑ 3B-the fibreglass company
- ❑ How glass fibre is produced
- ❑ How sizings work
- ❑ New sizings aimed at better properties
- ❑ The challenges of improving modulus of glass fibre
- ❑ Some laminates data
- ❑ Conclusions



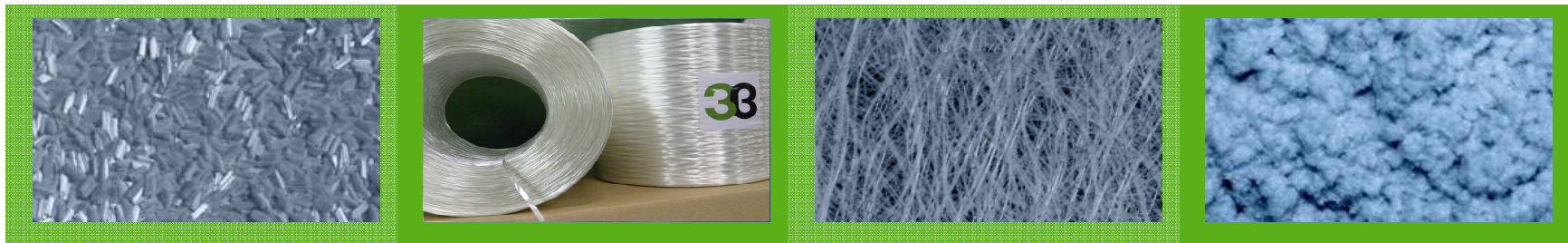


a reference in fibreglass...

innovative, entrepreneur and eco-enthusiast

Major and dynamic actor in **composite reinforcement solutions**

- ❑ A special focus on **thermoplastics, wind energy, performance composites**
- ❑ 1000 experts building upon a long heritage of 45 years of expertise
- ❑ 160 000 tons of glass produced per year



Innovating and setting new standards within the fibreglass industry based on our **two unique high performance and eco-responsible glass technologies: Advantex[®] glass and HiPer-tex[™]**

Advantex[®] is a registered trademark of Owens Corning used under license.

...with global presence

to most effectively serve our partners

□ Sales Offices

- Europe
 - **B**ruelles
- India
- USA
- China

□ Productions

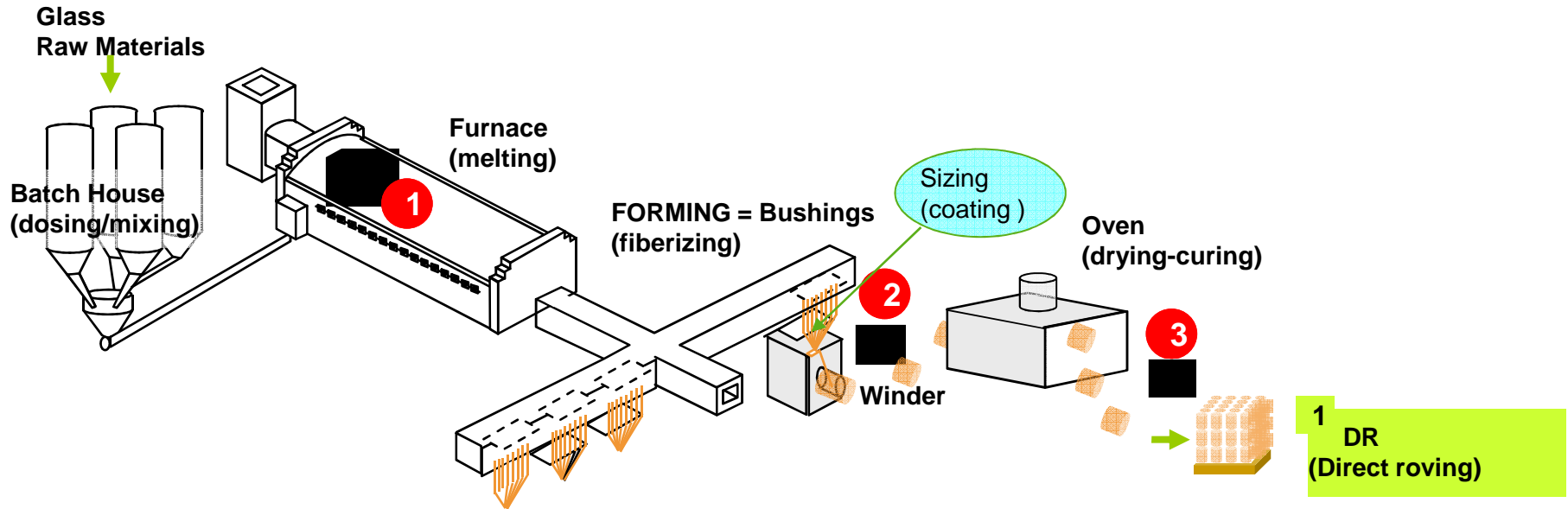
- **B**irkeland, Norway
- **B**attice, Belgium
- Goa, India

□ Research & Application Development

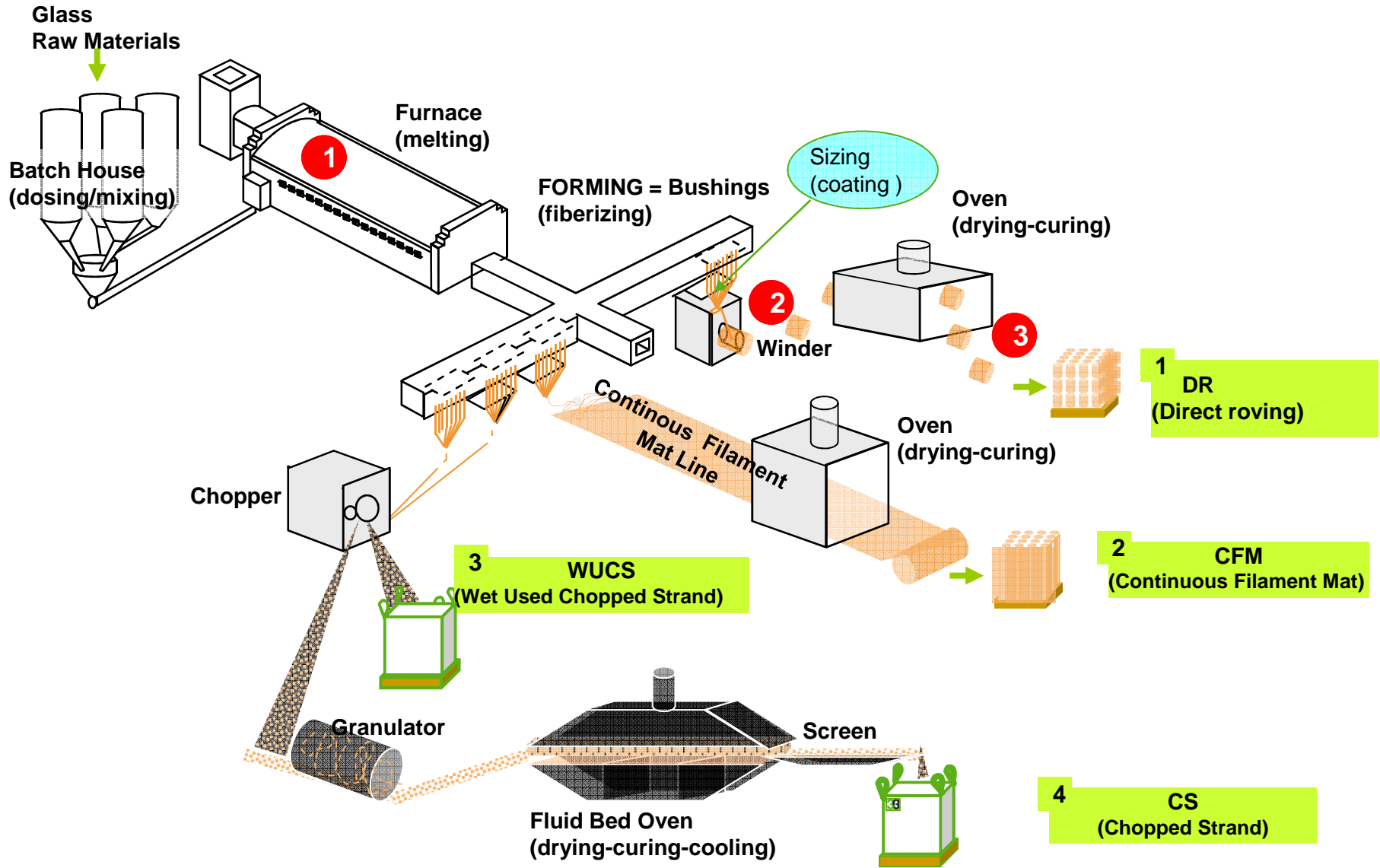
- Battice, Belgium (Lüttich, 25 km from Aachen)
- Activities in Glass – Fibre coating – Composite



3B glass fibre processes



3B glass fibre processes



Note : Multi end roving and Chopped Strand Mat from Goa plant not represented here

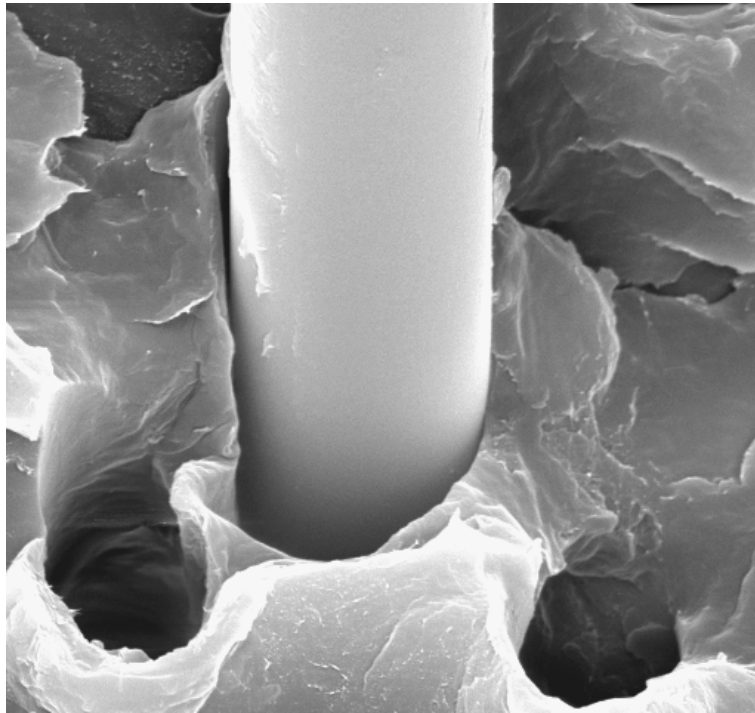
how sizings (or sizes) work

Size is applied as a water based formulation,

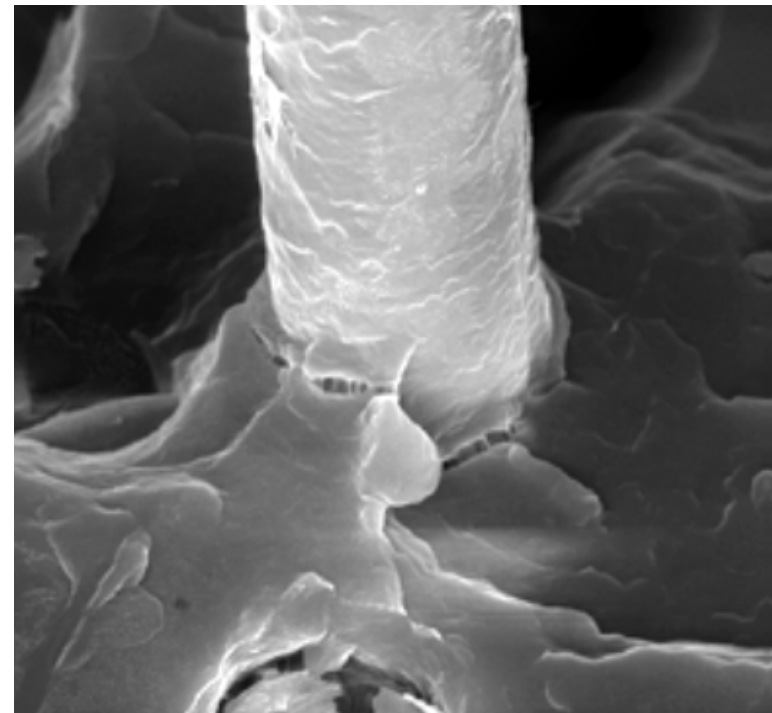
it contains:

- ❑ **Coupling agent(s)** : Provides adhesion between glass surface and the resin => Silanes,
- ❑ **Film Former(s)** : Provides protection and strand integrity to the roving as well as compatibility with the resin => EP, PU, VE, ...
- ❑ **Lubricant(s)** : Provides lubrication and protects the filaments during processing
- ❑ **Other Additives** : antistat, emulsifier, anti foaming, bactericide, ...

how sizings work



Poor adhesion
fibre debonding
fibre pull out



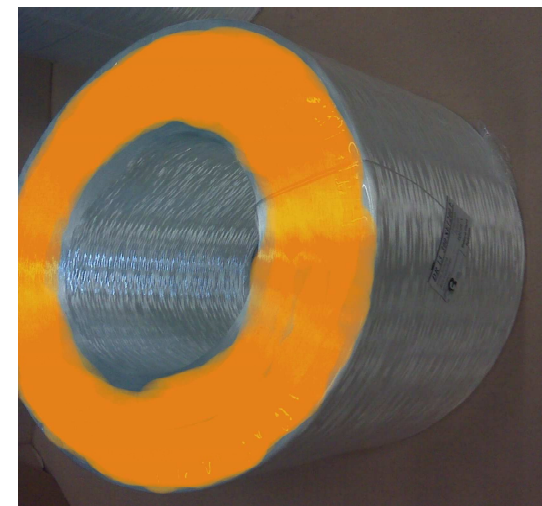
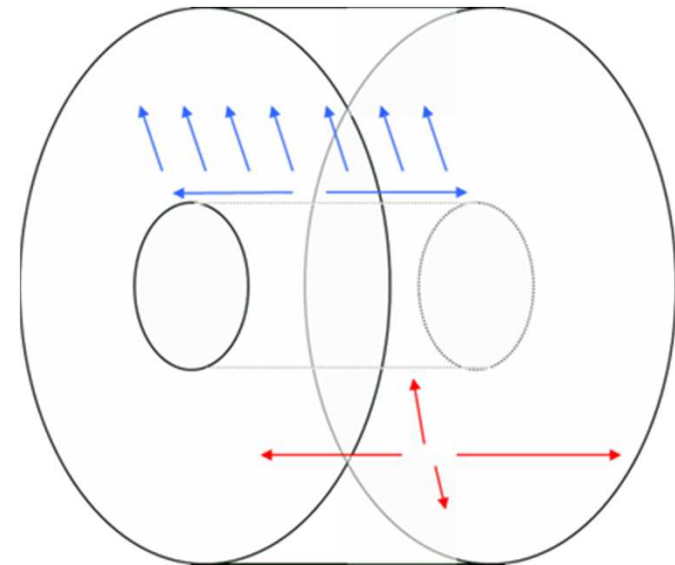
Good adhesion
cohesive failure



Courtesy of Professor Miravete-MIT

the « migration » issue

- ❑ Migration occurs due to **size centrifugation** and **water evaporation**
- ❑ Migration zones cannot be cleaned at bobbins flanges
- ❑ Sizing compatibility with the resin is key to achieve good laminate quality



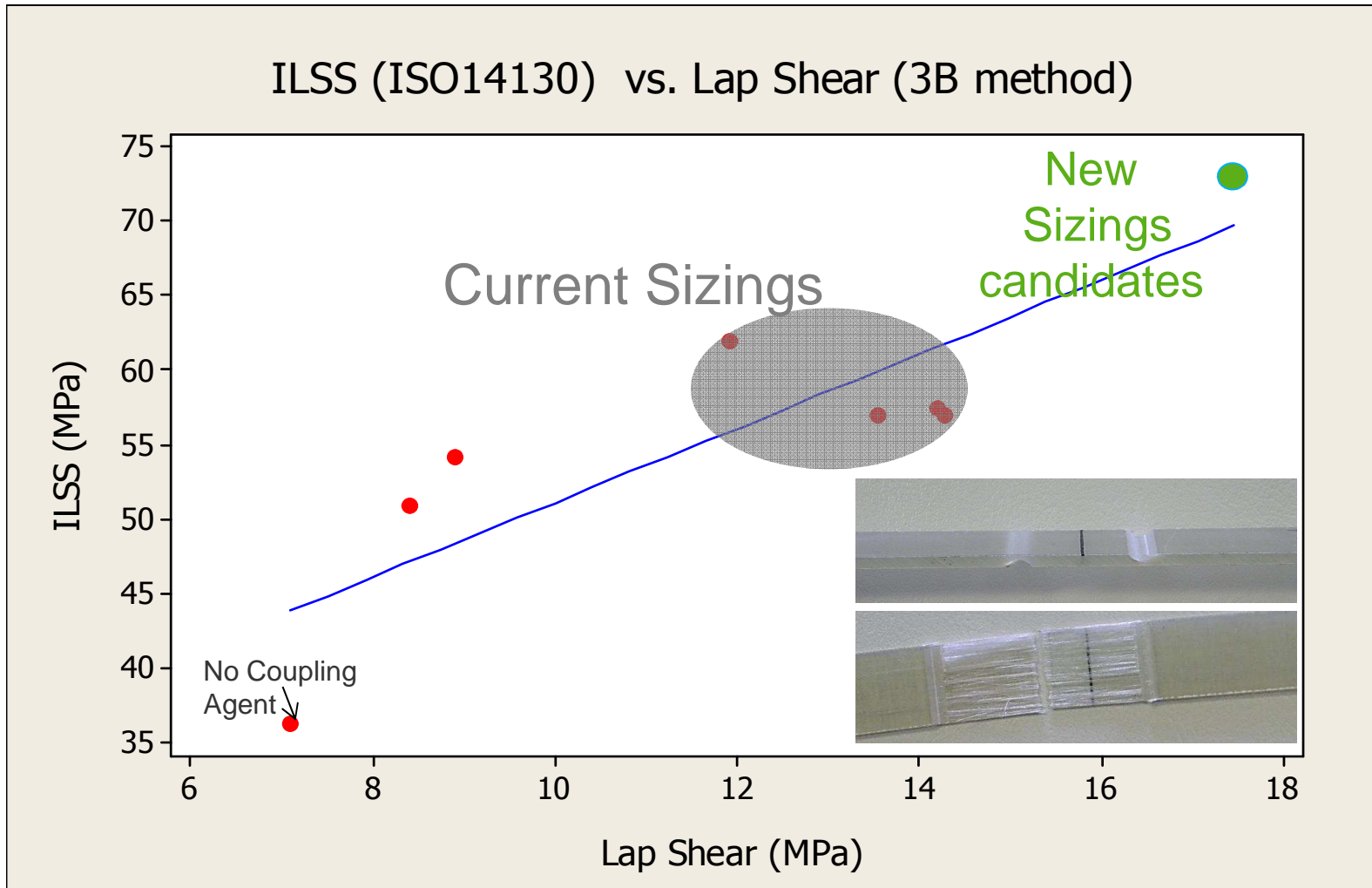
the development of the new sizing

the key points

- ❑ Focus on Epoxy (infusion and prepreg)
- ❑ Define the goals versus the benchmark
 - Improve Inter Fibre Strength and Inter Lamina Shear Strength
 - Improve fatigue performance
 - Improve processing (lower fuzz & static, wet-out, ...)
- ❑ Define testing methods
 - Design of Experiments
 - UD or Biax laminates based on infusion of “wound roving preform”
 - Evaluation on weaving and knitting machines

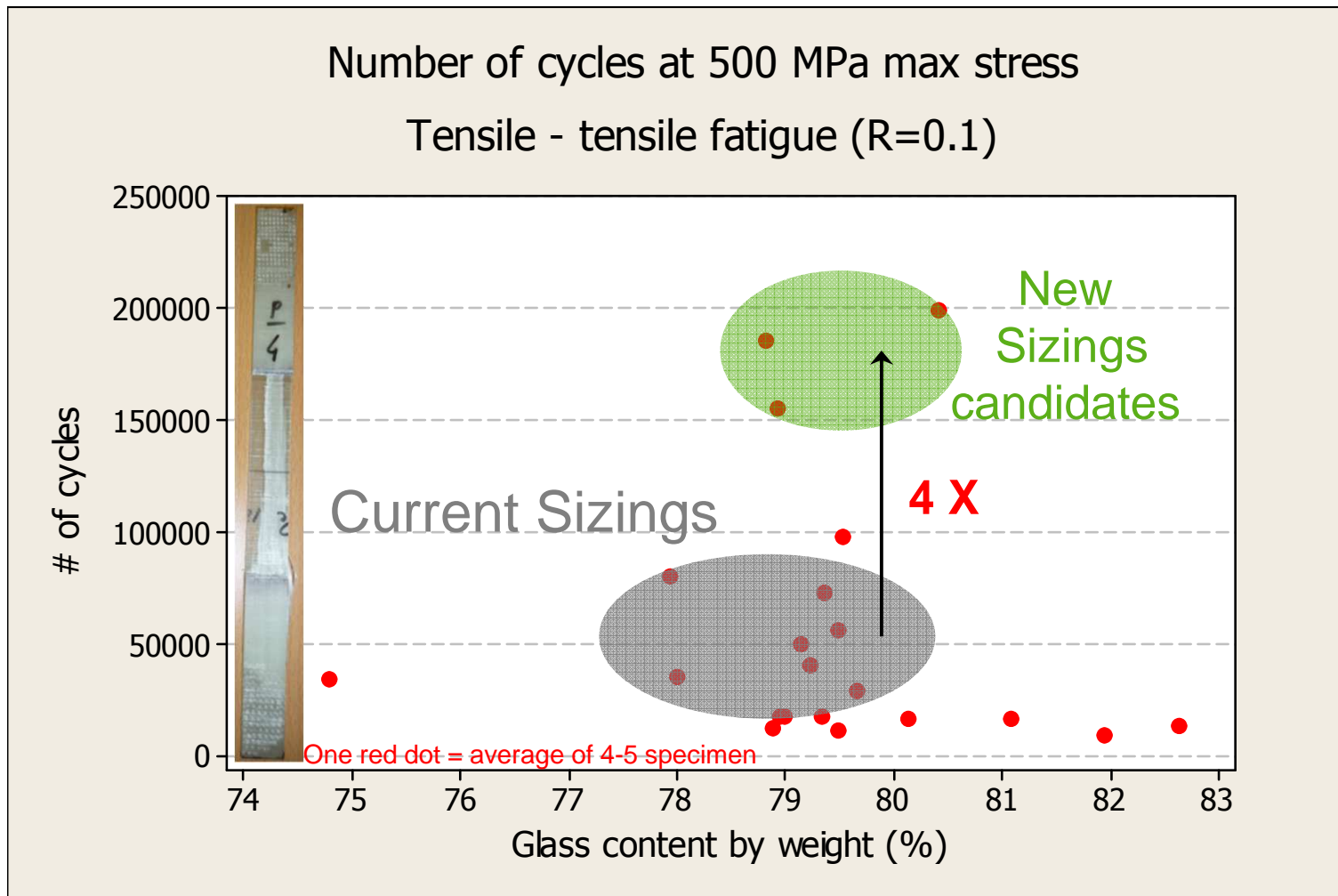
example of improvement

epoxy UD laminates



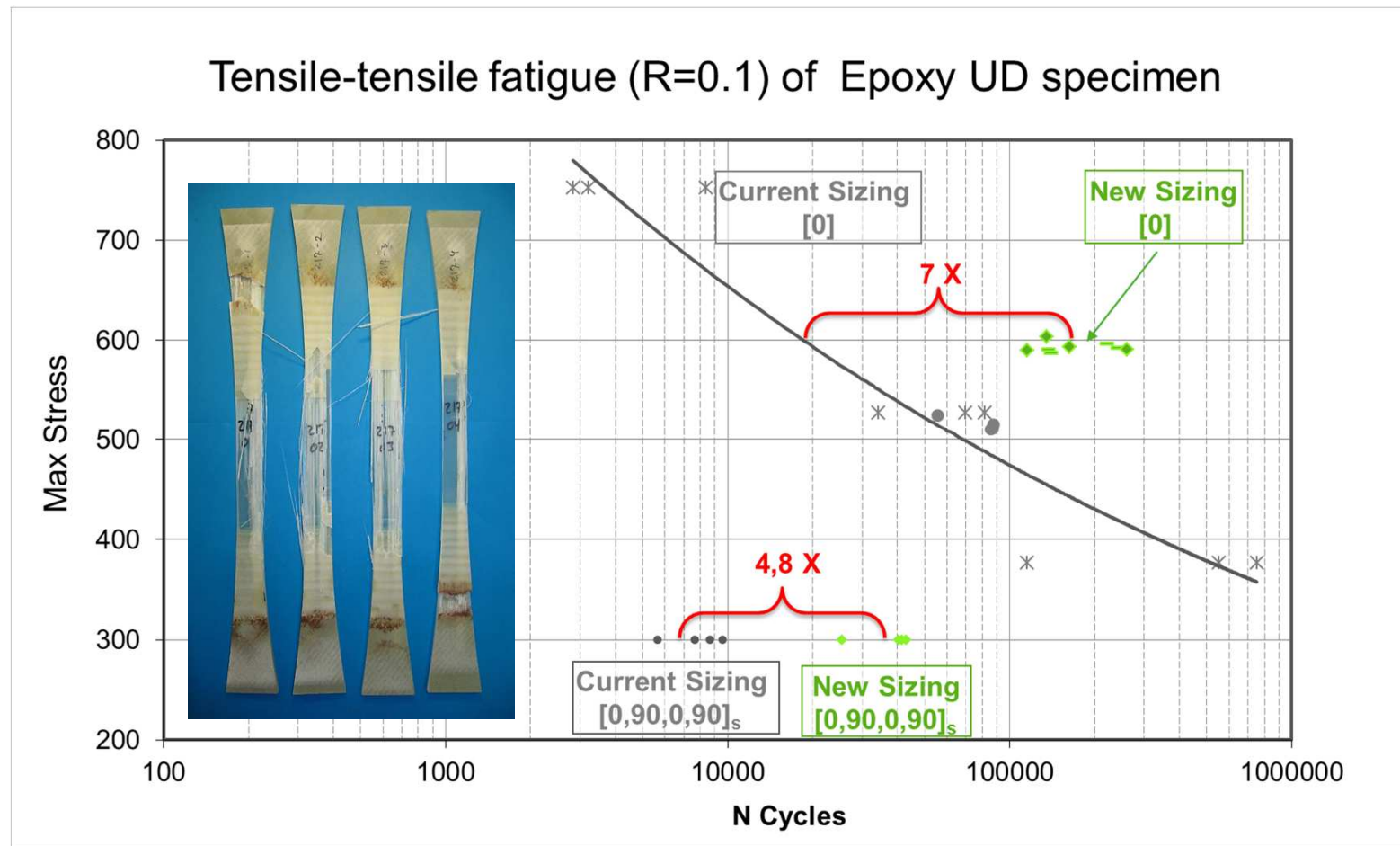
example of improvement

epoxy UD laminates



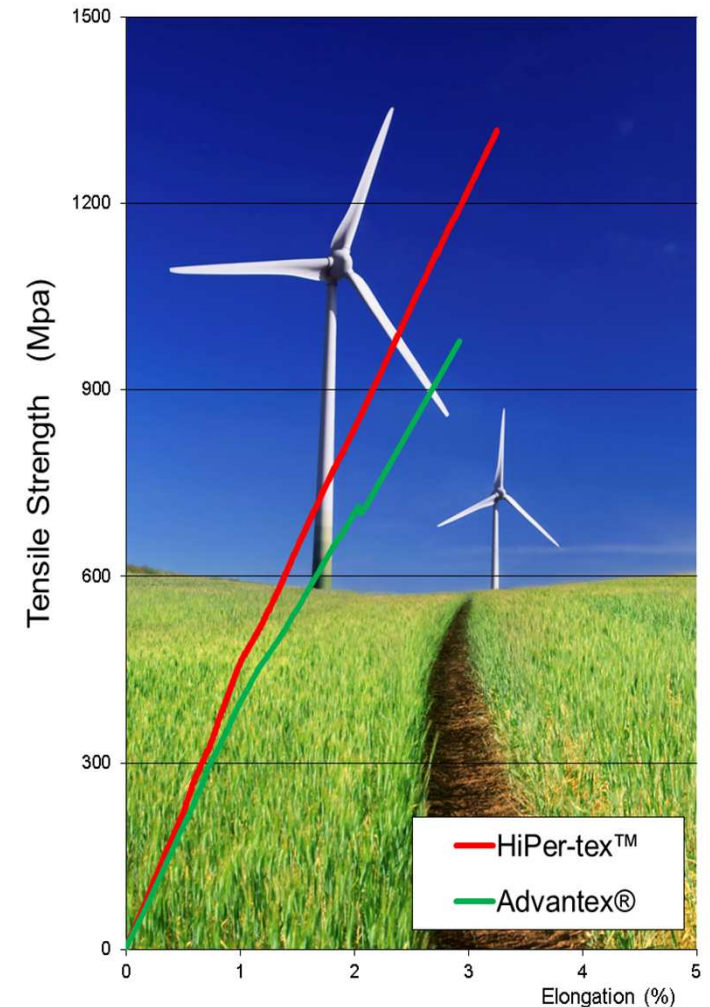
example of improvement

epoxy UD and Biax laminates



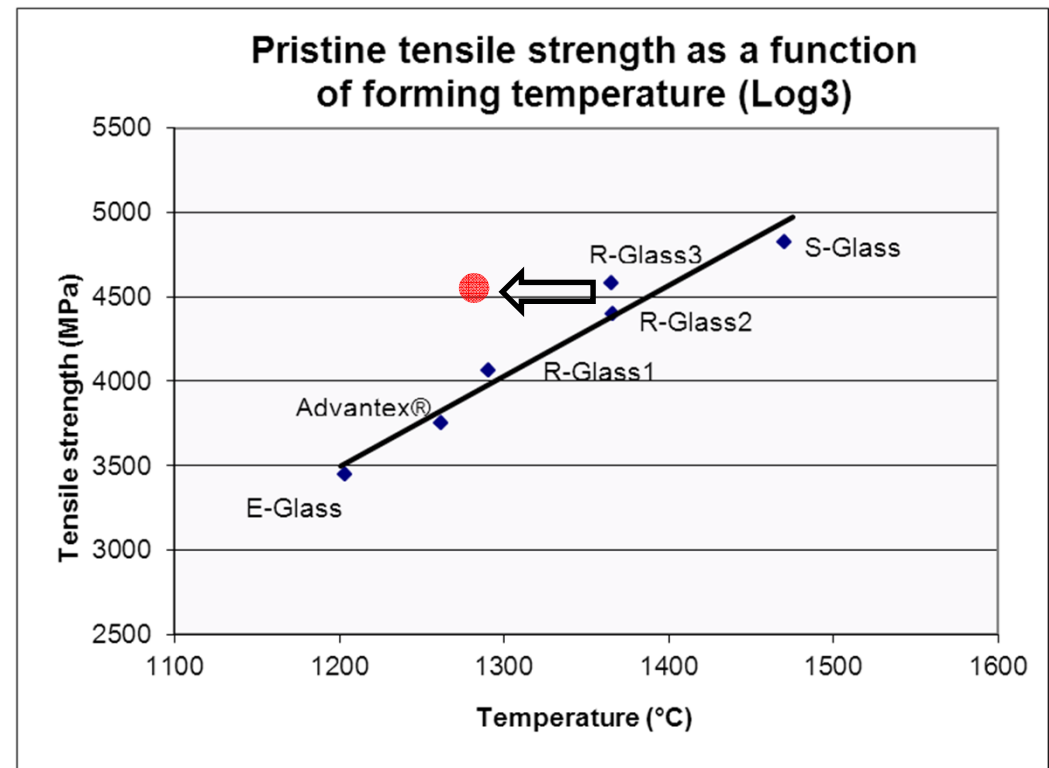
the challenges of improving glass fibre modulus

- ❑ Eco responsible glass technology
- ❑ Designed for large volume
- ❑ Compatible with existing processes through the value chain
- ❑ Cost competitive



3B the fibreglass company working (fibre forming) temperature

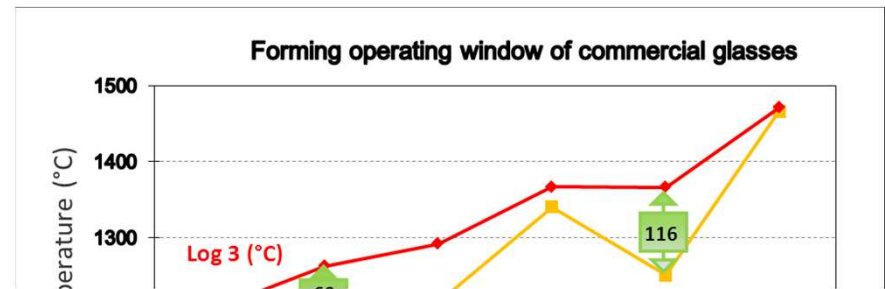
- Working temperature is traditionally named as T3 or log3
- It corresponds to the temperature at which glass viscosity is 1000 poises (= 100 000 mPa.s)
- T3 depends on
 - glass composition
 - network formers
- Those network formers are also influencing mechanical properties



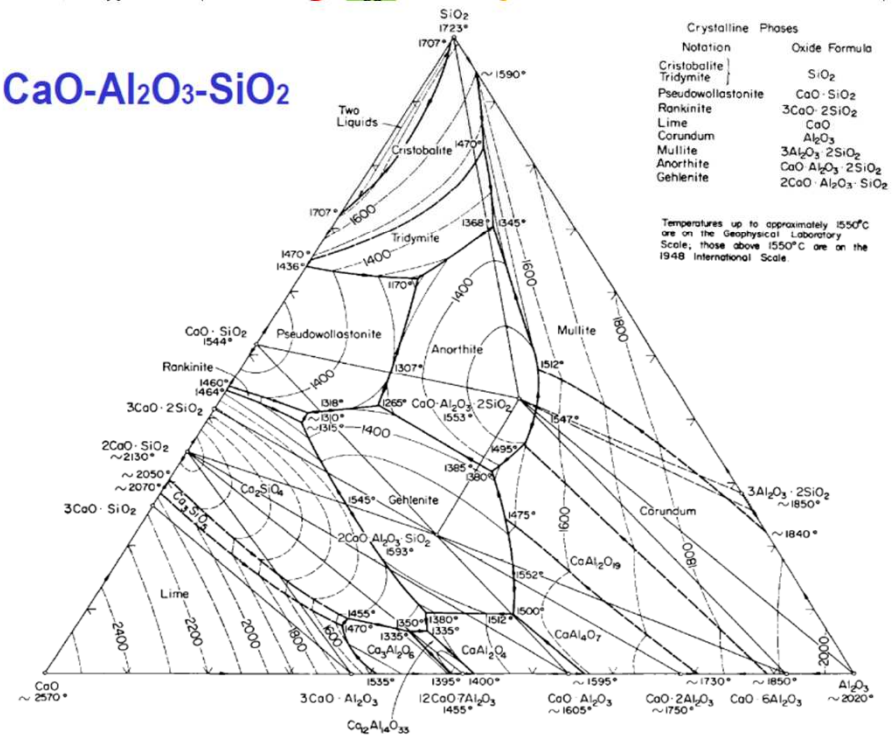
Higher energetical cost to produce higher performance fibreglass =>
This is the first challenge to face

forming operating window

- ❑ Liquidus Temperature (T_{liq}) is defined as the highest temperature at which cristalization can occur
- ❑ Cristalization is not allowed in direct forming process
- ❑ A minimal difference between T_3 and T_{liq} (ΔT) is needed : 65°C
- ❑ This temperature is depending on glass composition
- ❑ There is no robust extended model allowing to predict T_{liq}



CaO-Al₂O₃-SiO₂

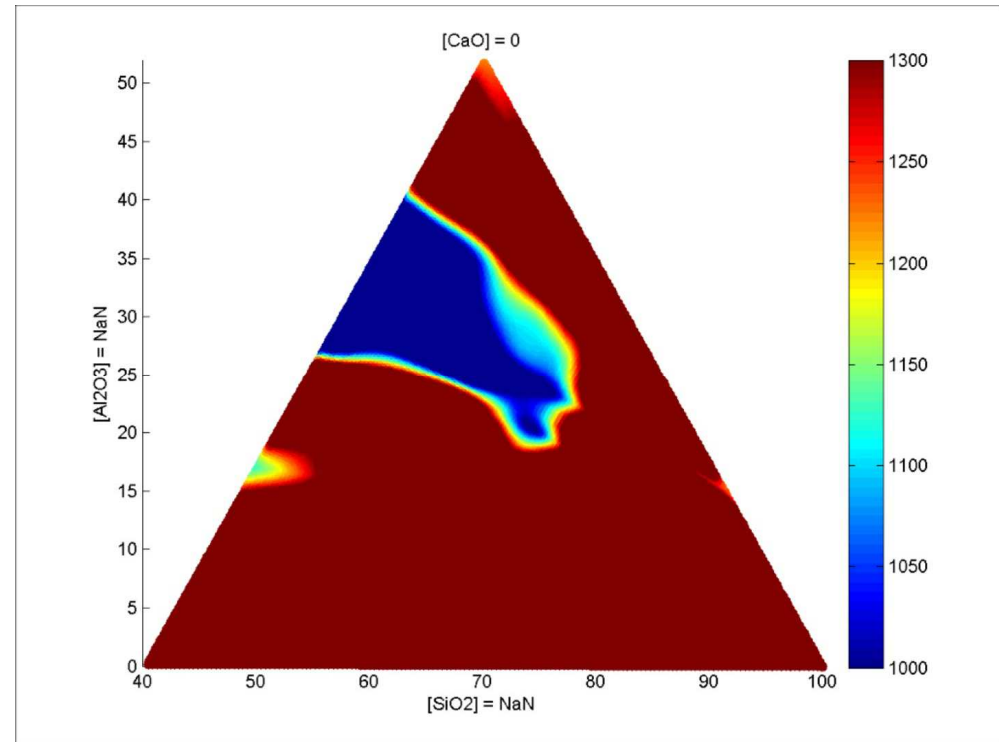
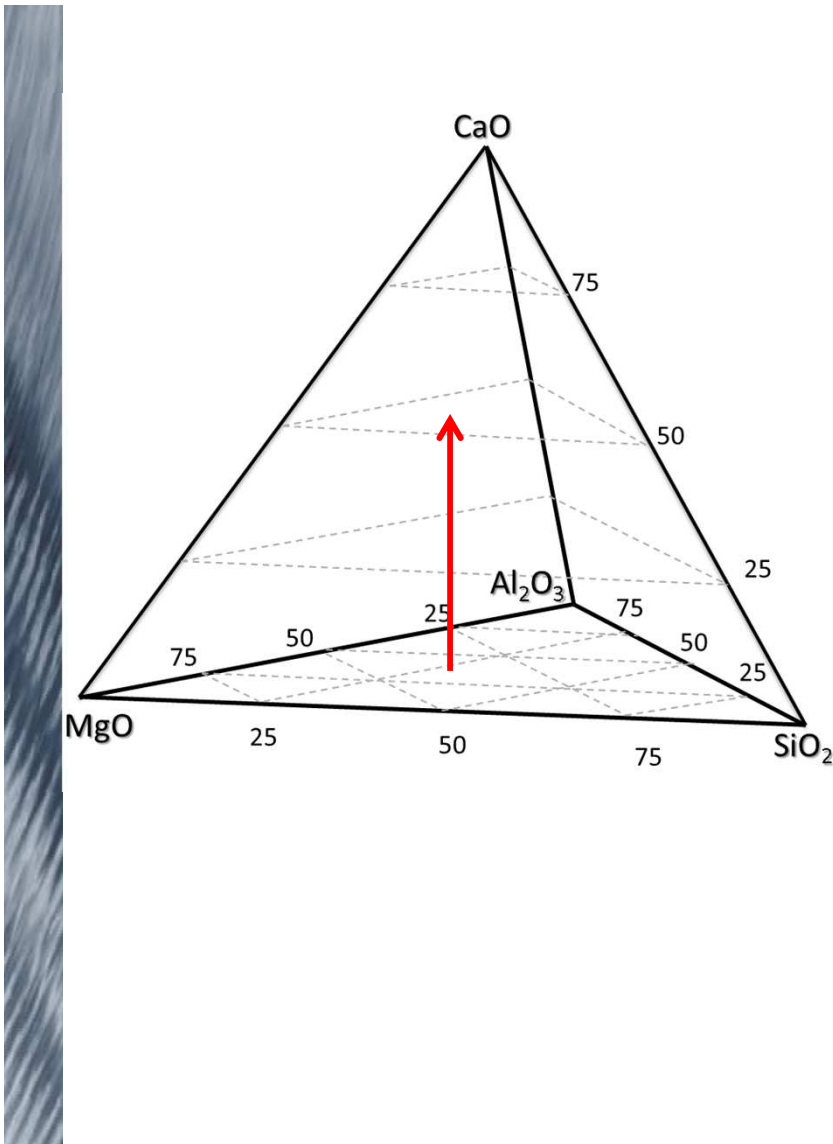


Lowering T_3 means a need to lower $T_{liquidus} \Rightarrow$

high interest in finding extended models : second challenge to face

T Liquidus model

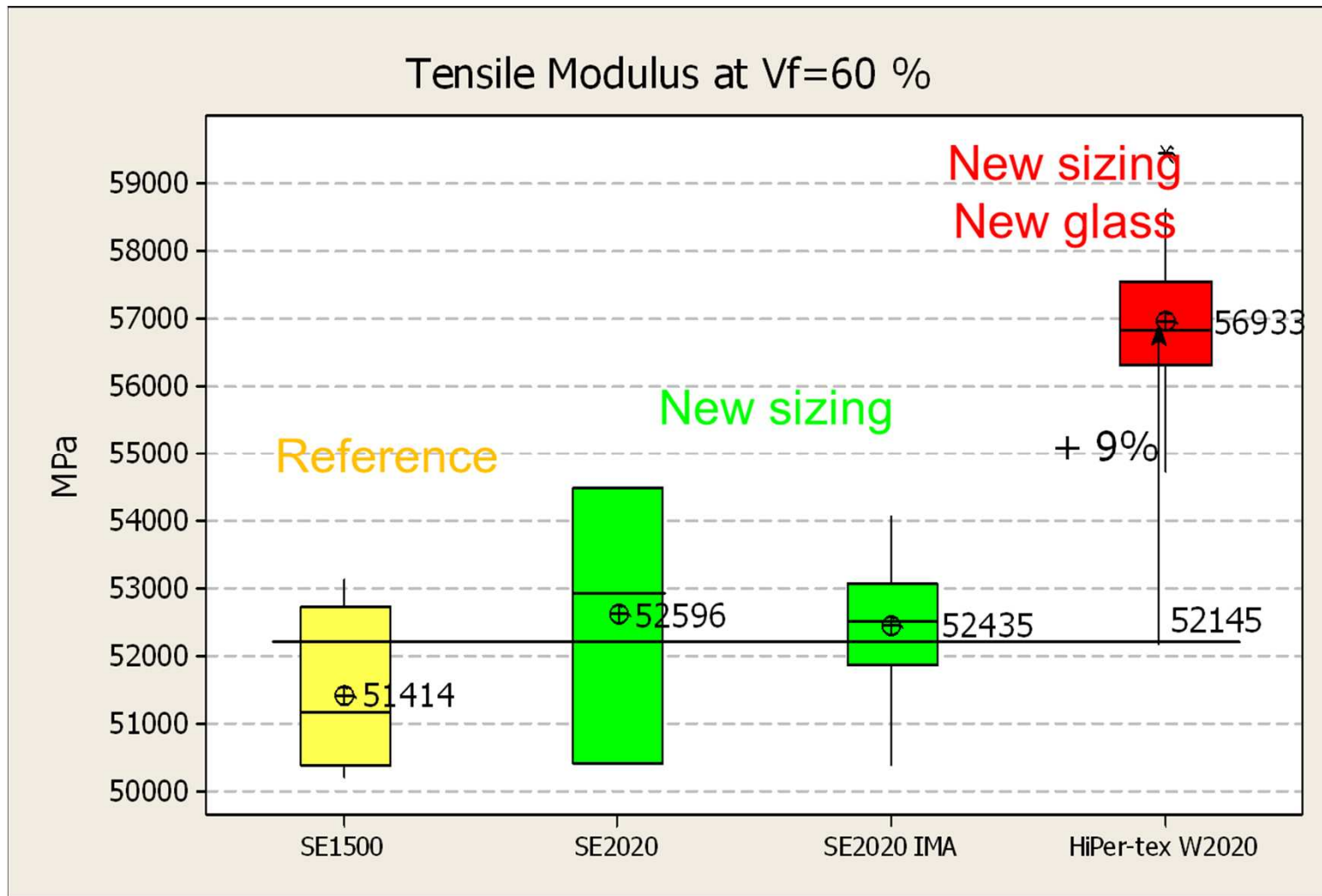
quaternary model (SiO₂, Al₂O₃, CaO, MgO)



Video illustration :
ternary diagram for various CaO levels

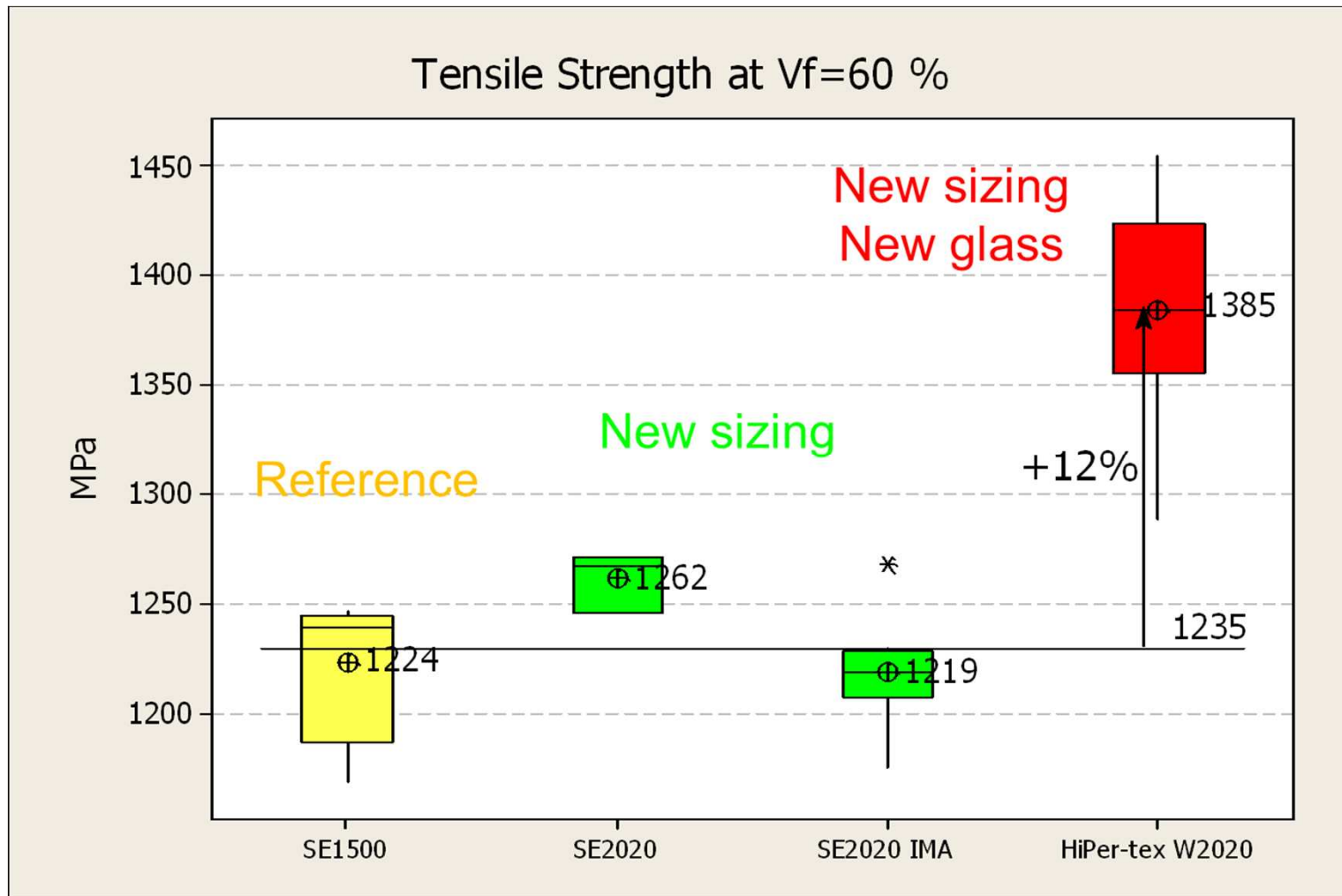
HiPer-tex™ vs. Advantex®

UD epoxy laminates



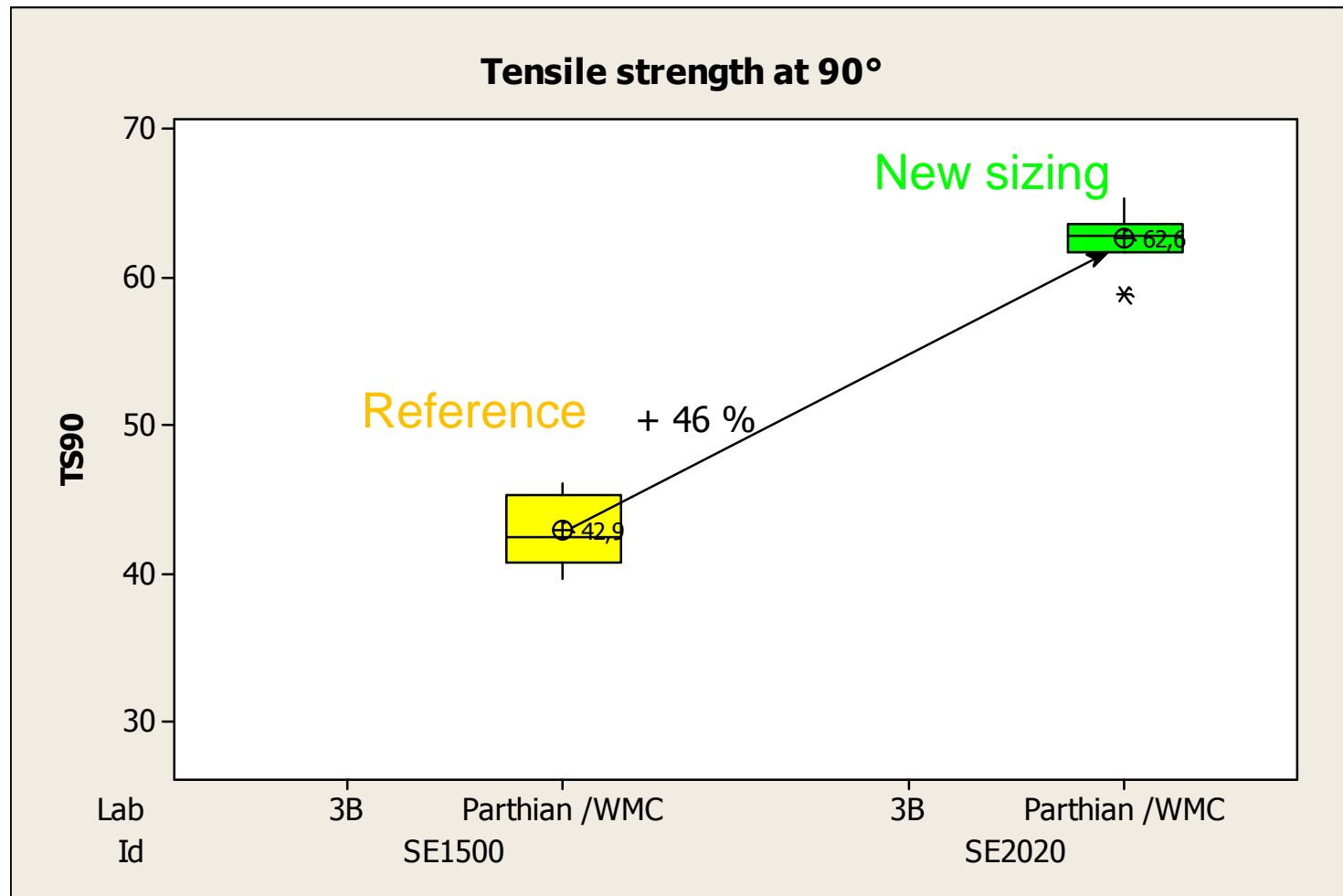
HiPer-tex™ vs. Advantex®

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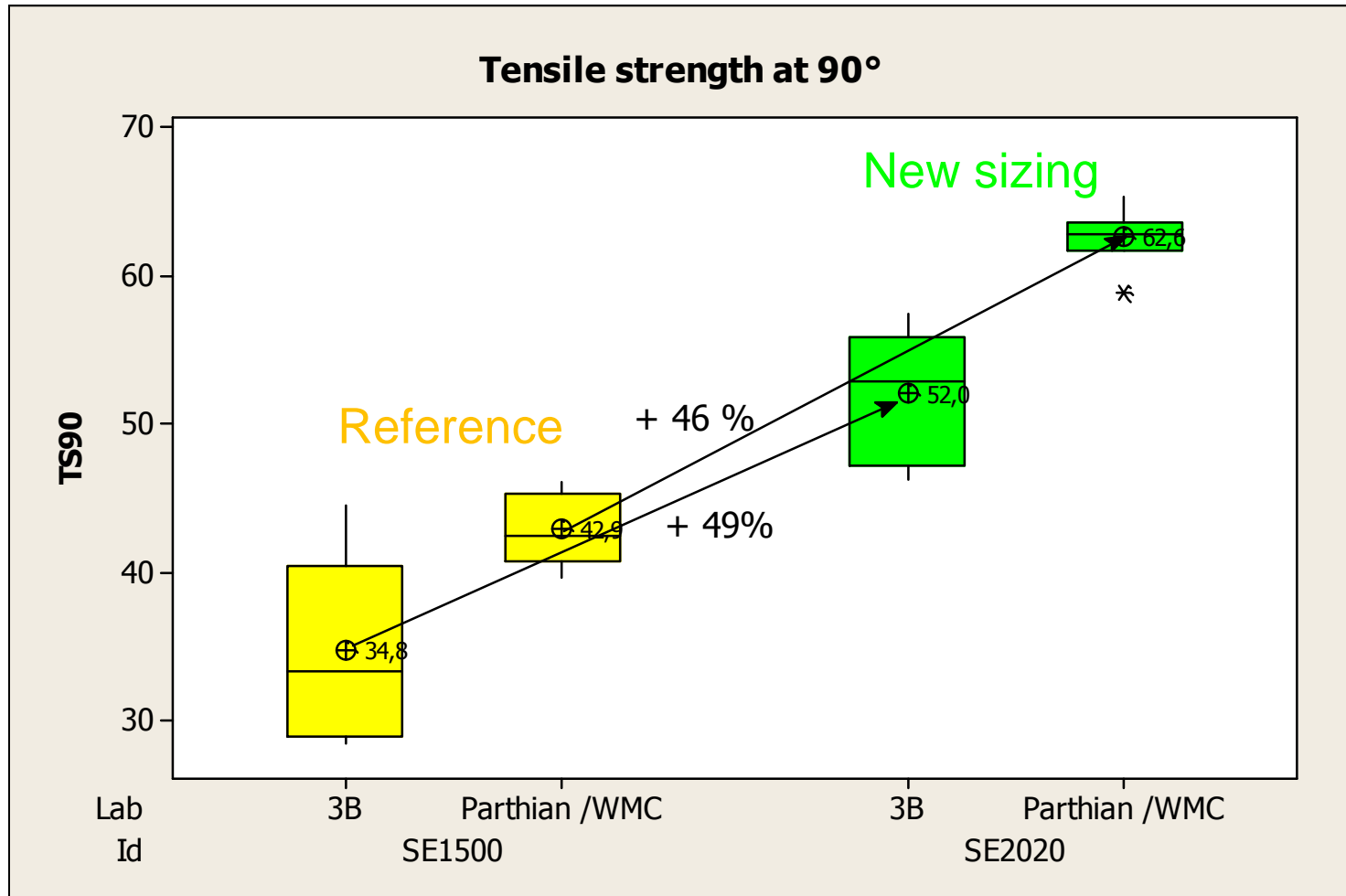
spar caps laminates properties

UD 1150 Advantex fabric / epoxy laminate



spar caps laminates properties

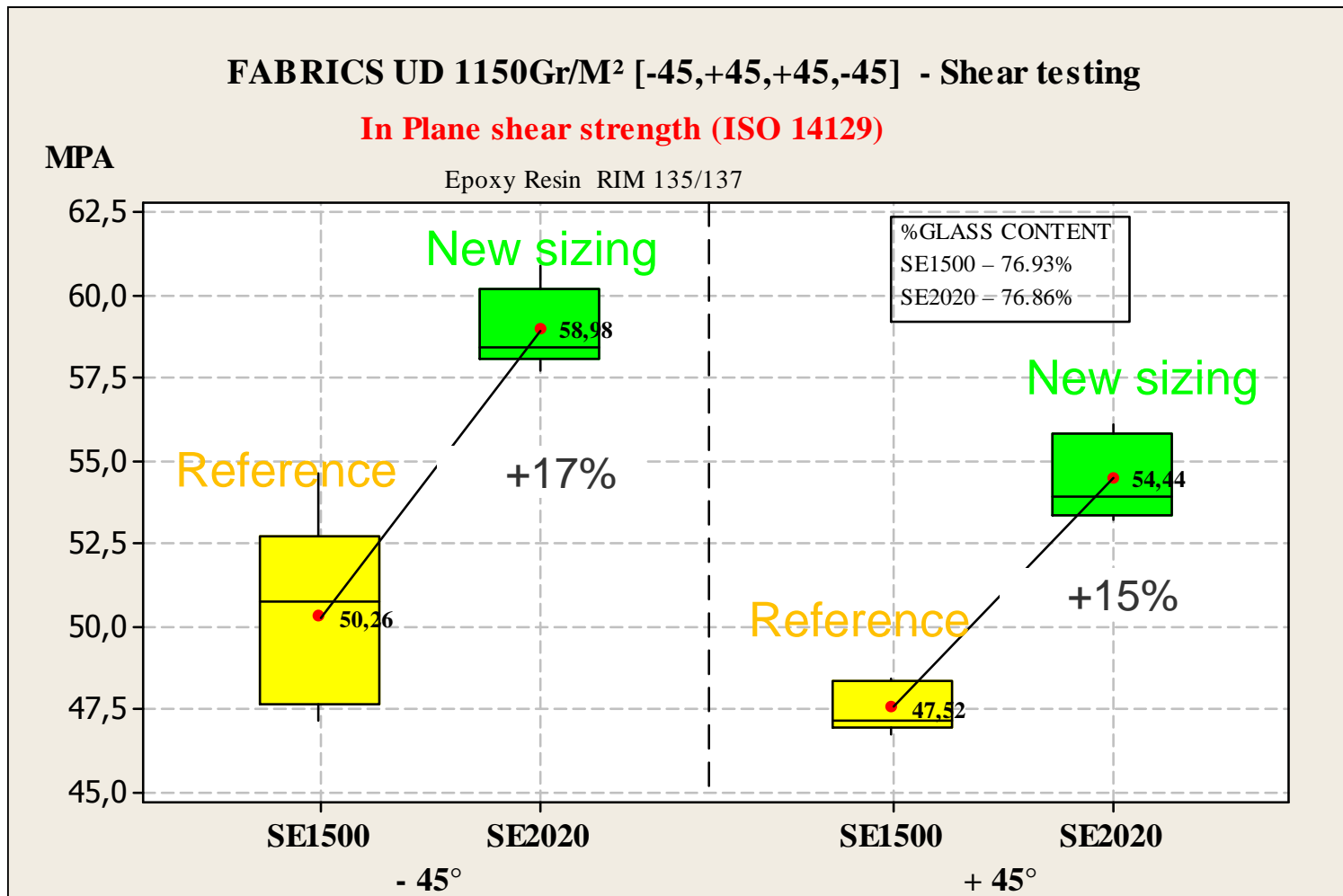
UD 1150 Advantex fabric / epoxy laminate



Note: For 3B testing the weft reinforcement was removed !
 Less dispersion for Parthian/WMC results, especially for SE2020

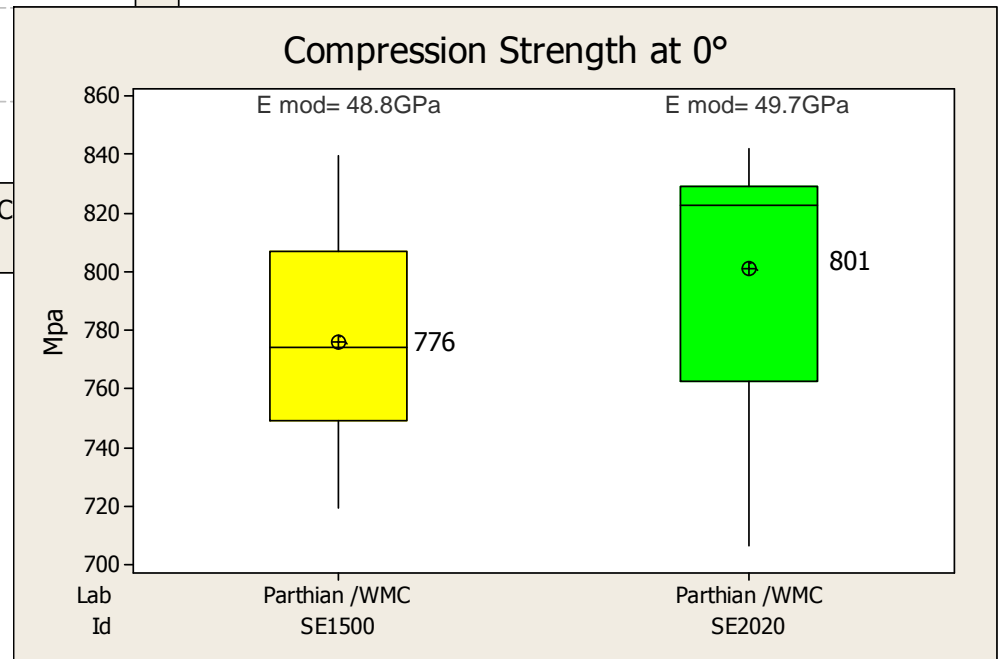
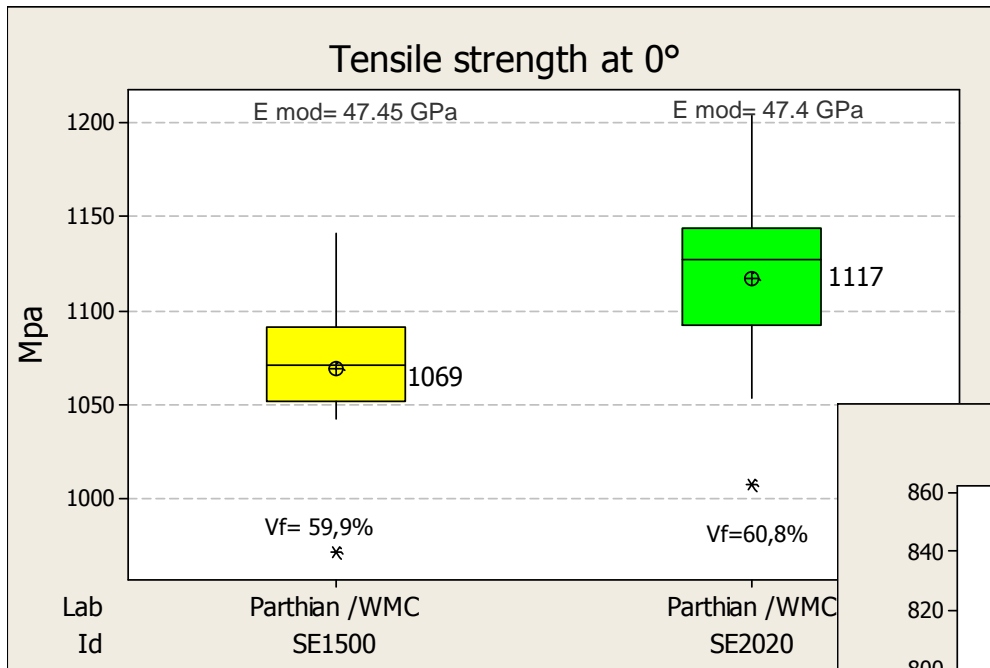
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UD 1150 Advantex fabric / epoxy laminate



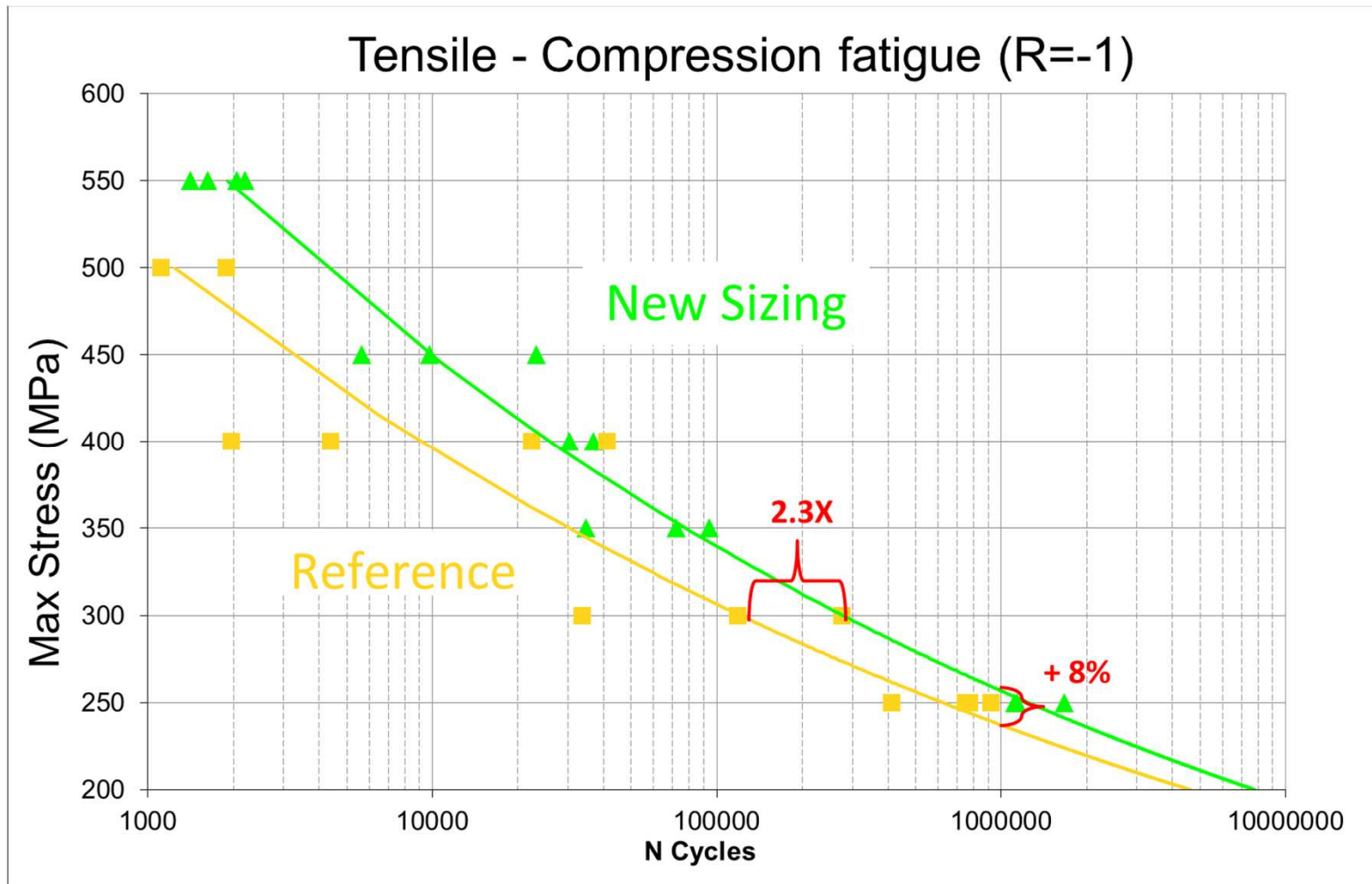
spar caps laminates properties

UD 1150 Advantex fabric / epoxy laminate



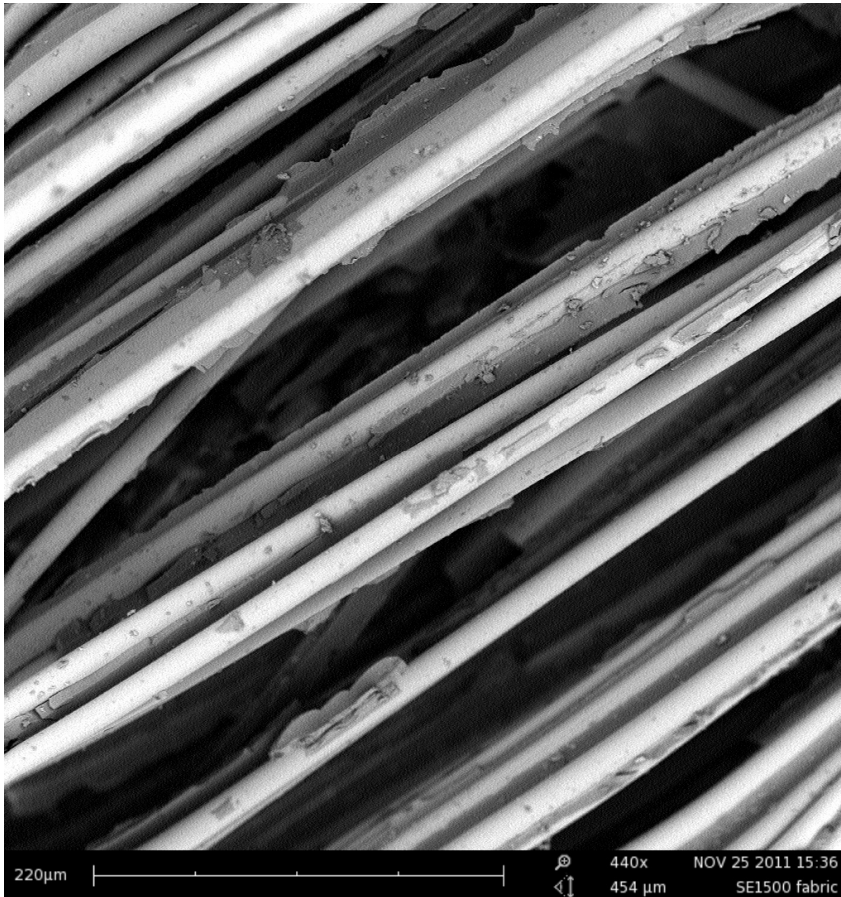
spar caps laminates properties

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Glass volume fraction : Reference- SE1500 = 59%, New sizing – SE2020 = 58.4%

Typical pictures from SEM analysis of the 90° tensile fracture

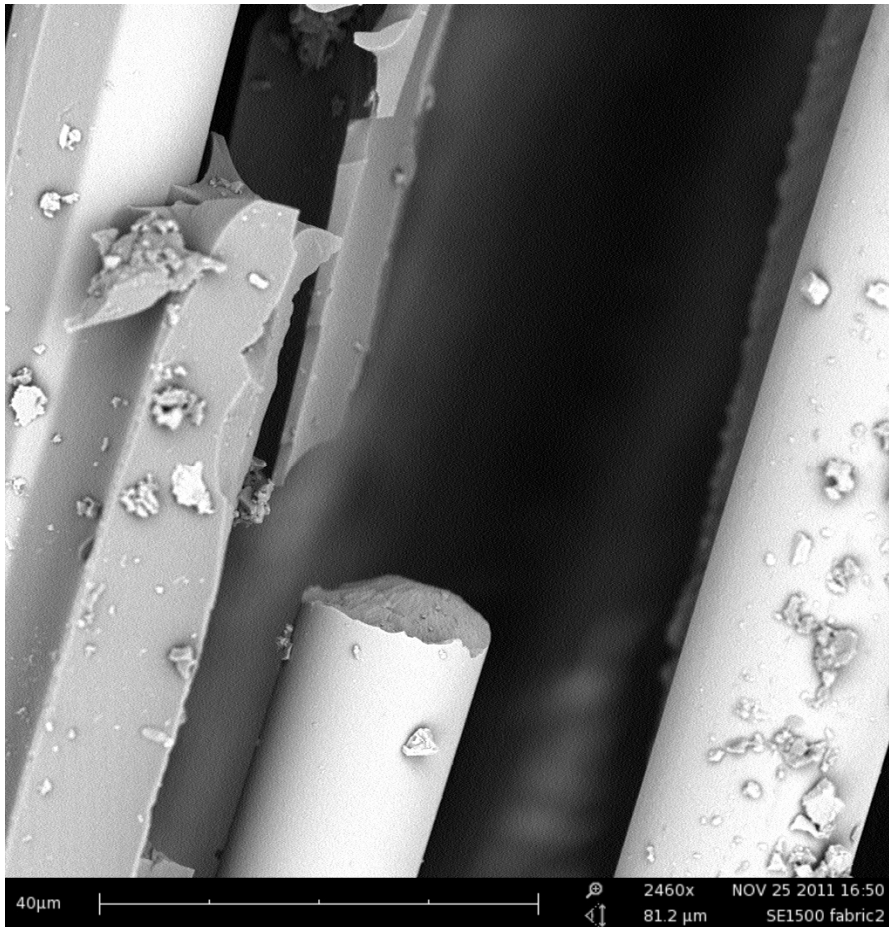


Reference SE1500

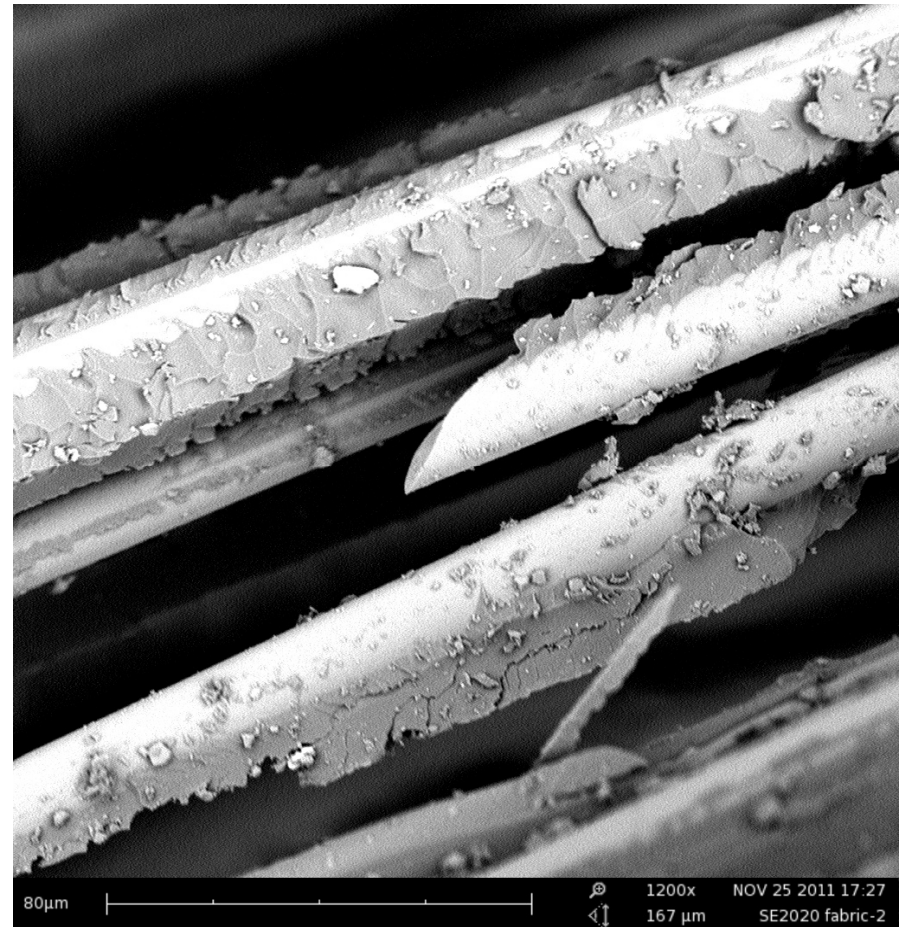


New Sizing SE2020

Typical pictures from SEM analysis of the 90° tensile fracture



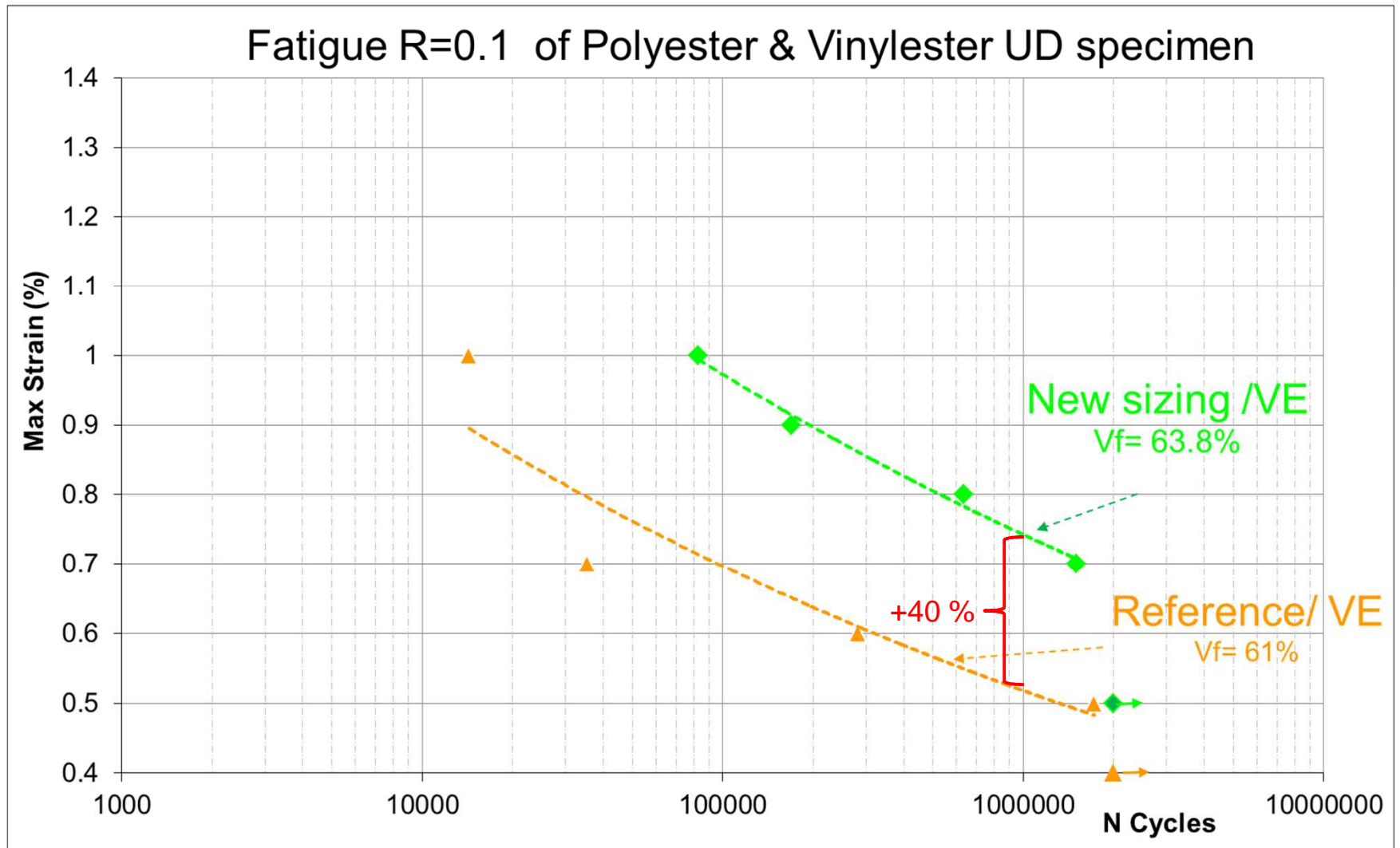
Reference SE1500



New sizing SE2020

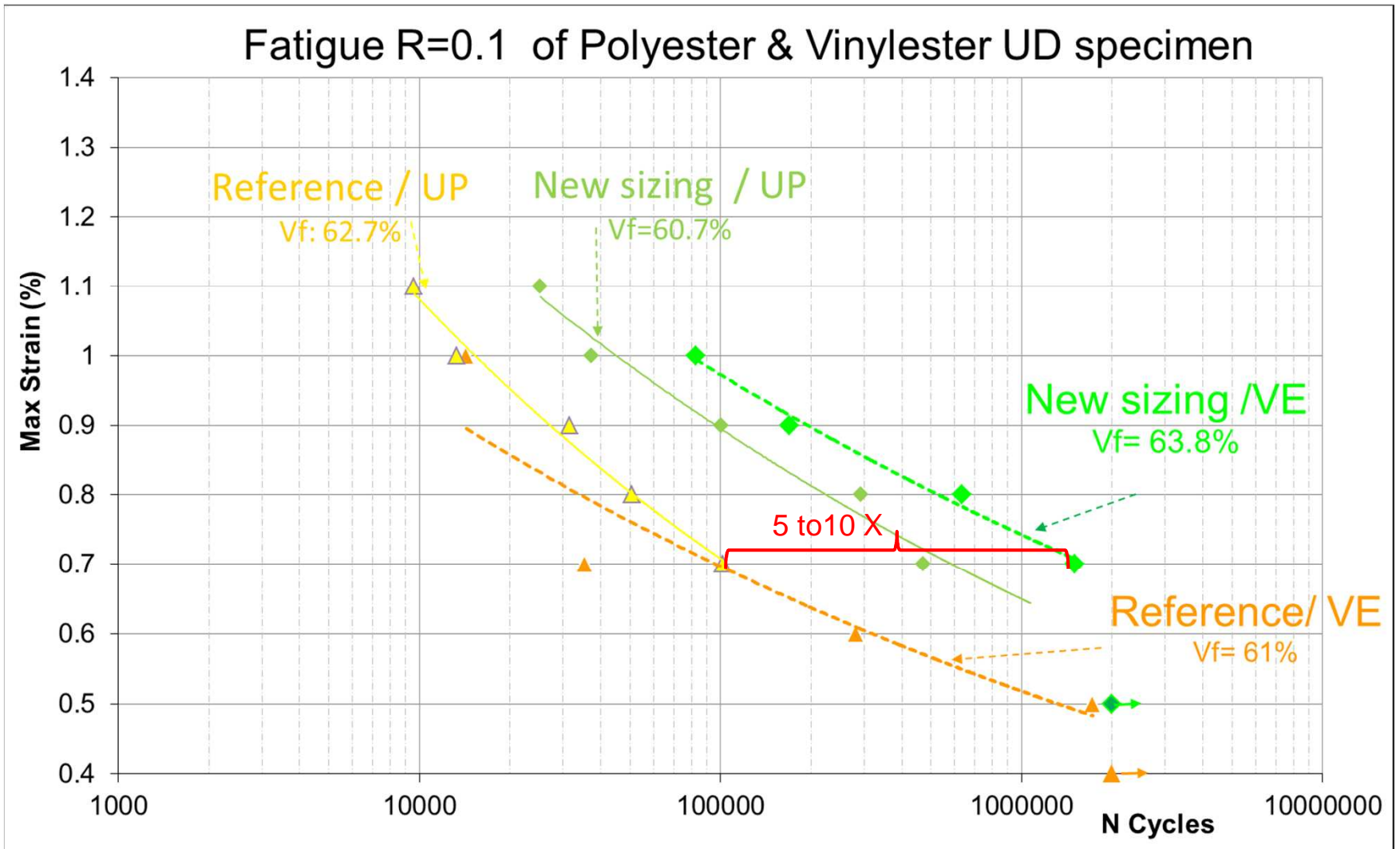
Also for Polyester and Vinylester

UD laminates



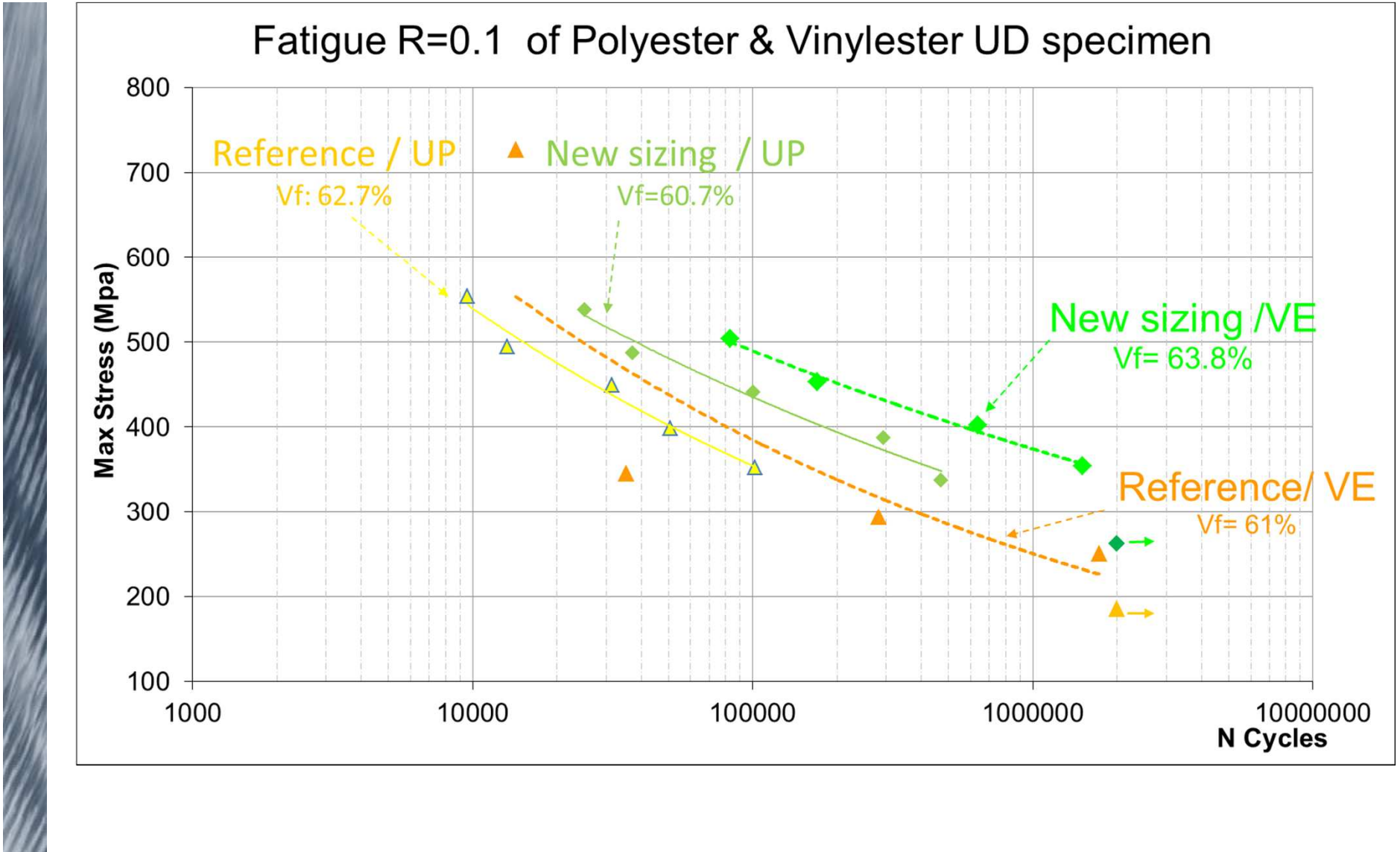
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Also for Polyester and Vinylester

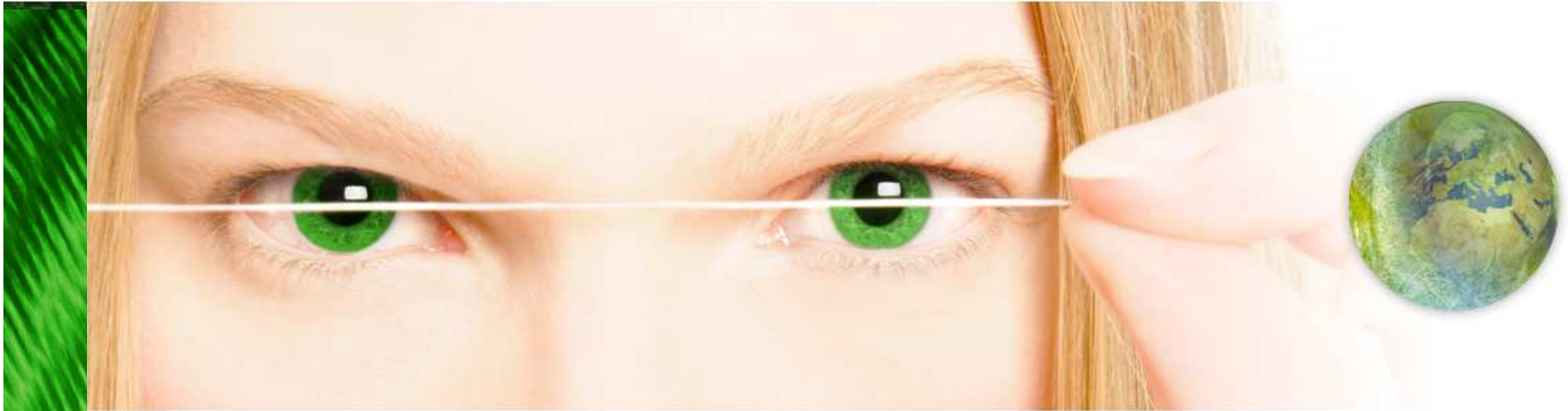
UD laminates



- 3B recent sizings and glass developments are leading to improved performances of glass fibre composites
 - Transverse Tensile Strength close to resin strength has been achieved
 - In Plane shear and Inter Laminar Shear Strength are « boosted »
 - E Modulus is raised to 56 GPa (for UD laminates at 60%Vf)
 - Tensile strength is enhanced by 10-25%
 - Improvement in Fatigue (R=0.1) in the order of a decade vs. traditional E glass
- SE2020 & SE3030 on Advantex® glass and W2020 & W3030 on HiPer-tex™ high performance glass are 3B new solutions for lighter, longer and/or stronger blades.

Thank you for your attention





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