BIO-BASED COMPOSITES WITH DIFFERENT MOISTURE CONTENTS UNDER STATIC AND DYNAMIC LOADING

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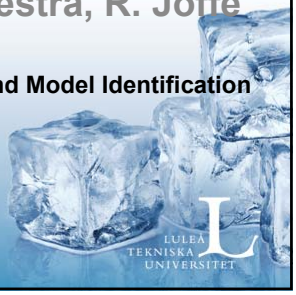

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INTRODUCTION

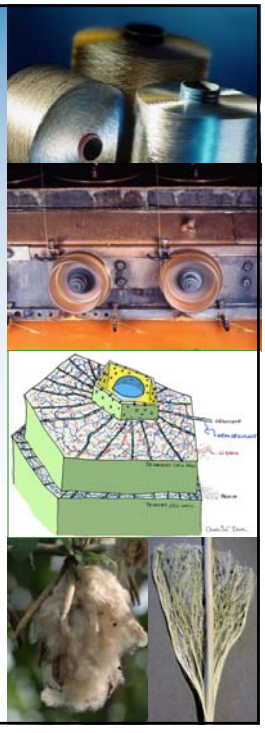
NATURAL FIBERS COMPETING GLASS FIBERS!

+ Renewable and biodegradable
+ Low specific weight
+ Very good specific stiffness
+ Good specific tensile strength

– Low impact strength
– Temperature sensitivity
– Water absorption
– Variability of properties

Dynamic loading vs. Static loading

- Long term applications
- Most of the damage occurring in fatigue
- No specific fatigue life prediction algorithm



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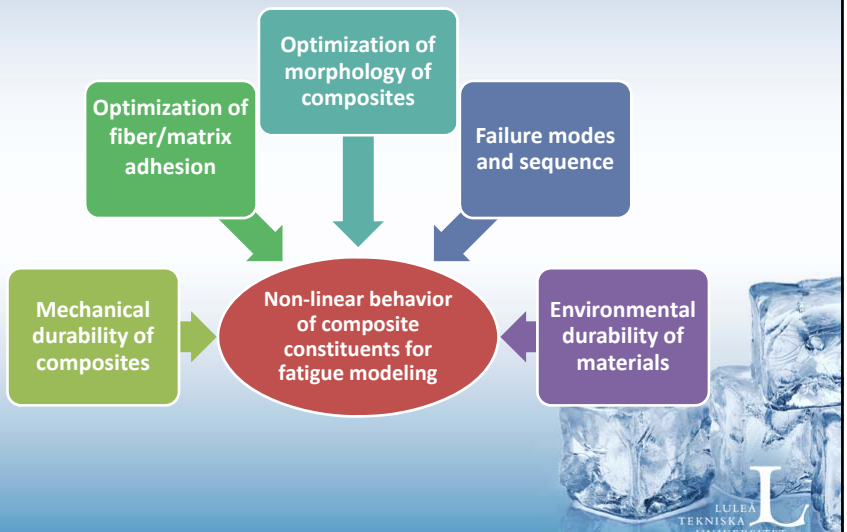
OBJECTIVES

Developing High Performance Bio-Composites



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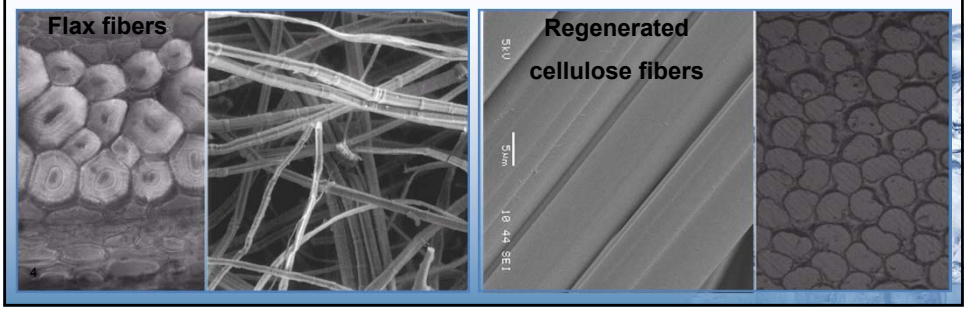
MATERIALS

Natural vs. Man Made

Fibers	Density (g/cm3)	Modulus (GPa)	Strength (MPa)	Strain (%)	Length (mm)	Diameter (µm)	Specific Modulus	Specific Strength
E-glass	2,54	72	3530	1,8-3,2	Cont.	10	28,2	1390
Wood	1,54	30-40	400-800	-	3-5	20-40	~25	~390
Flax	1,4-1,5	50-70	500-900	1,5-2,4	13-70	10-30	~41	~480
Hemp	1,48	30-60	300-800	1,1-2	5-55	10-50	~30	~370
Sisal	1,45	9-20	510-700	2,2-2,9	1-8	10-40	~10	~420
RCF	1,5	~20	700-800	13-15	Cont.	12,5	~13	~470



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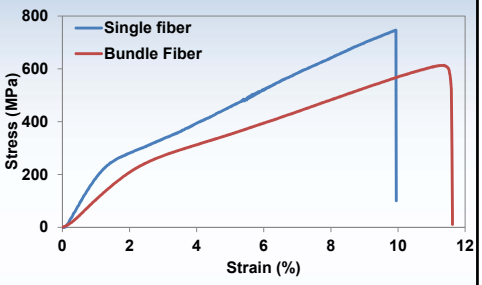
MATERIALS

Characteriazation and Identification

RCF	Bundle fibers	Single fibers
Young's Modulus (GPa)	17,4 ± 0,8	21,9 ± 1,9
Strain at Failure (%)	10 ± 1	8 ± 1
Tensile Strength (MPa)	655 ± 27	745 ± 54



Materials

Fibers	Resins	Composites
RCF Cordenka 700 super 3	Epoxy-LY556 (E) *Huntsman*, USA	RCF/EpoBioX (CEB)
GF Typical E-glass fiber	Tribest (T) *Cognis GmbH*, Germany	RCF/Tribest (CT)
	EpoBioX (EB) *Amroy*, Finland	GF/EpoBioX (GEB)
		GF/Tribest (GT)

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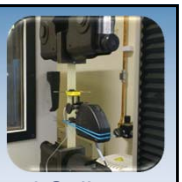
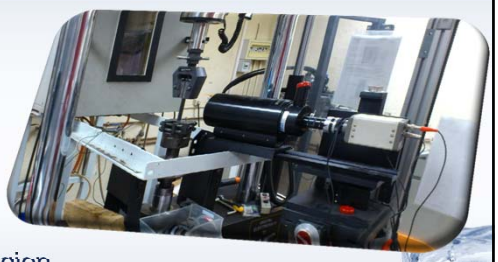
EXPERIMENTS



1. Moisture uptake 40% and 70% Relative Humidity
2. Static tensile testing INSTRON 3366, 10kN Load Cell
3. Fatigue testing
   - Tension-tension fatigue
   - Load ratio=0.1
   - Frequency 1Hz



- Stress level at linear elastic region

  EpoBioX $0.15\sigma_{UT}$ (1X of static rate)
  RCF/EpoBioX $0.20\sigma_{UT}$ (5X of static rate)
  GF/EpoBioX $0.25\sigma_{UT}$ (10X of static rate)

- INSTRON universal testing machine (model 1342) 8500 Digital Control, 5kN Load Cell

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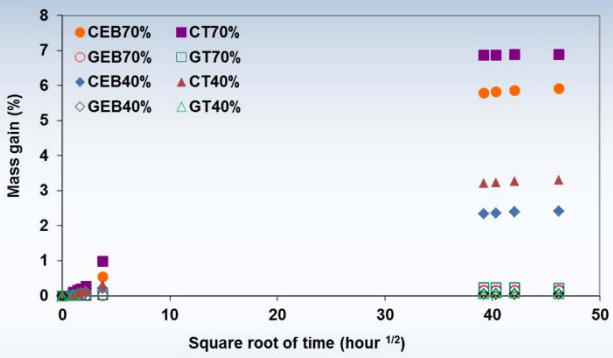
RESULTS

Moisture Uptake



Saturation Point

Resins			Composites		
RH	40%	70%	RH	40%	70%
Tribest	0,5	1,1	RCF/EpoBioX	2,4	5,9
Epoxy	0,2	0,4	RCF/Tribest	3,3	6,8
EpoBioX	0,2	0,5	GF/EpoBioX	<0,1	0,1
			GF/Tribest	<0,1	0,2

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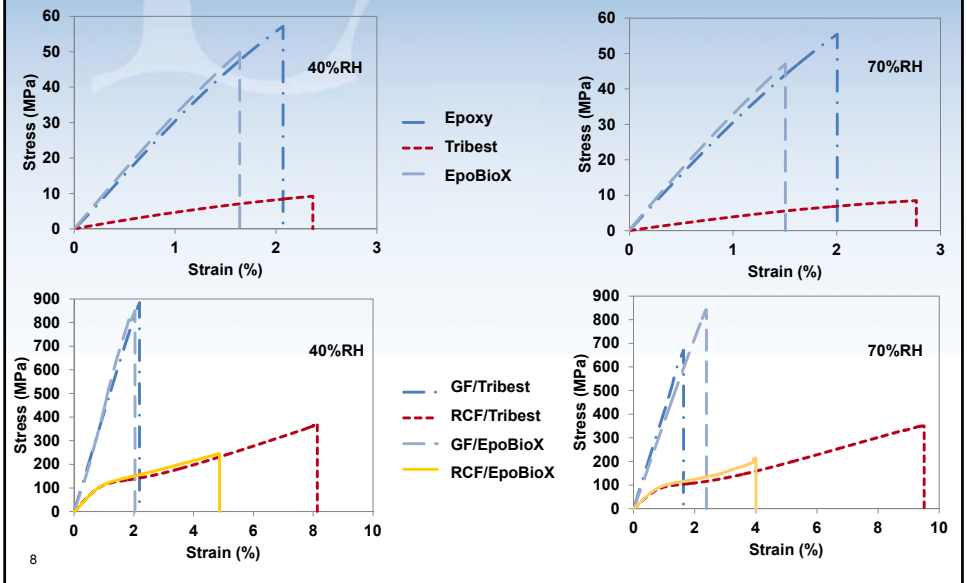
RESULTS

Stress-Strain Curves



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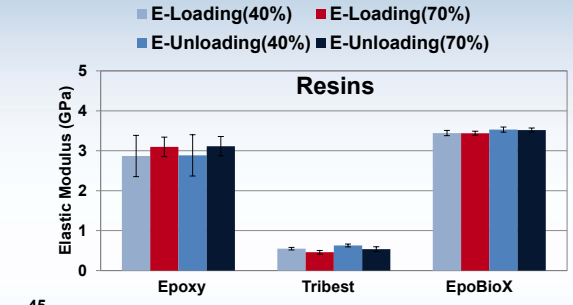
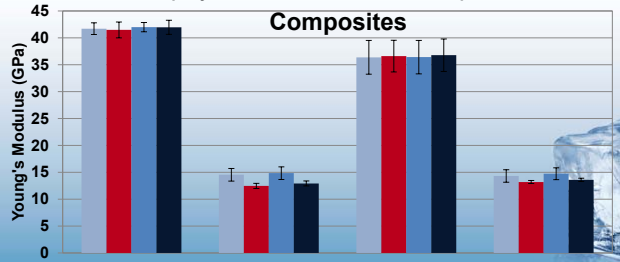
RESULTS

Modulus of Elasticity

Fiber	E-Modulus
RCF	~20 Gpa
GF	72 GPa
From Literature	





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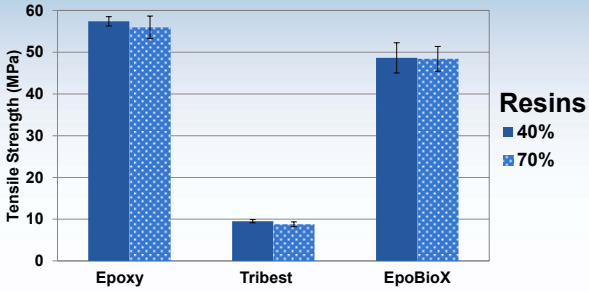
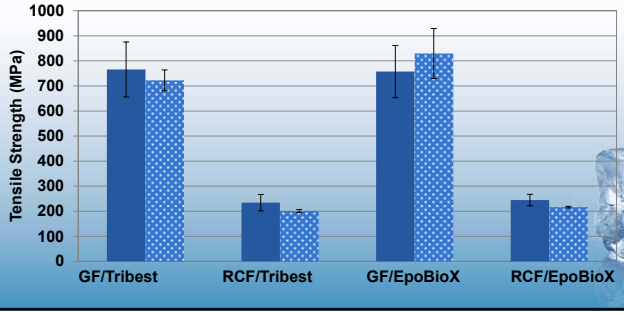
RESULTS

Ultimate Tensile Strength





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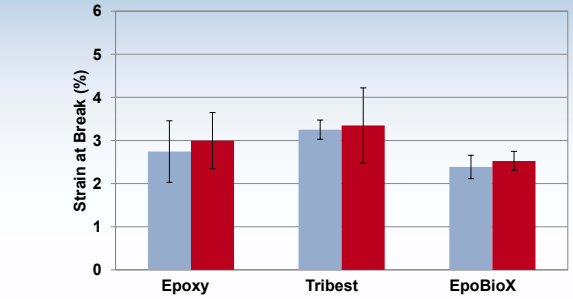
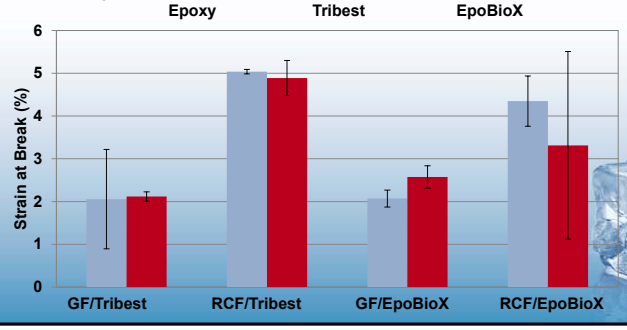
RESULTS

Strain at Failure





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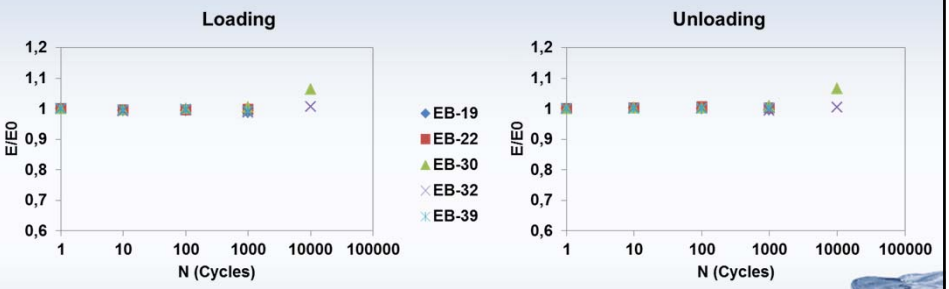
EPOBIOX

RESULTS

Stiffness Evolution

FATIGUE STRESS INTERVAL : [1-10] MPa



- Stress level of $0.15\sigma_{UT}$
- Humidity conditioned at 40% RH
- Range of E measurement (0.01-0.1%)
- Plasticity conditioned at:
  - EB-30: 40MPa-2h
  - EB-22: 45MPa-10+20+30+60min

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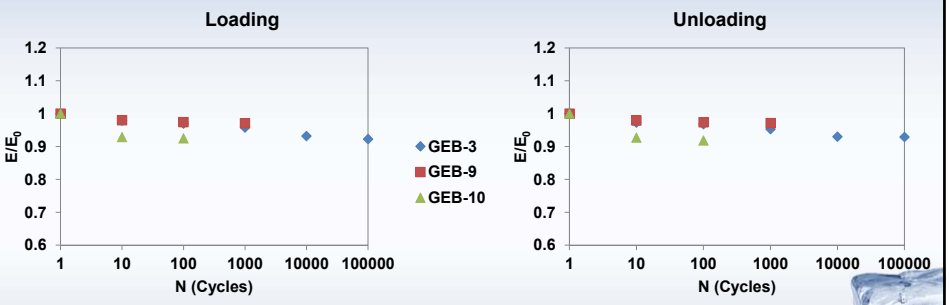
GF/EPOBIOX

RESULTS

Stiffness Evolution

FATIGUE STRESS INTERVAL : [19-190] MPa



- Stress level of $0.25\sigma_{UT}$
- Humidity conditioned at 40% RH
- Range of E measurement (0.01-0.1%)

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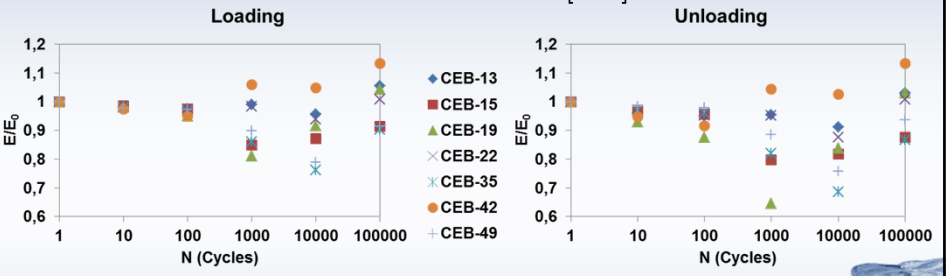
RCF/EPOBIOX

RESULTS

Stiffness Evolution

FATIGUE STRESS INTERVAL: [5-50] MPa



- Stress level of $0.15\sigma_{UT}$
- Humidity conditioned at 40% RH
- Range of E measurement (0.01-0.1%)
- Plasticity conditioned at 160 Mpa
  - CEB-49: 2h
  - CEB-35: 2h
  - CEB-42: 10+20+30+60min

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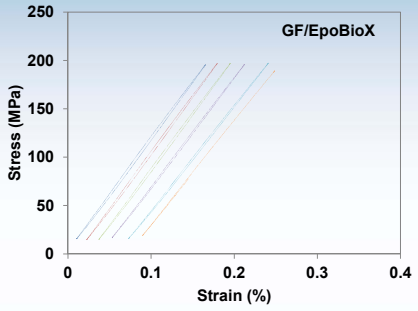
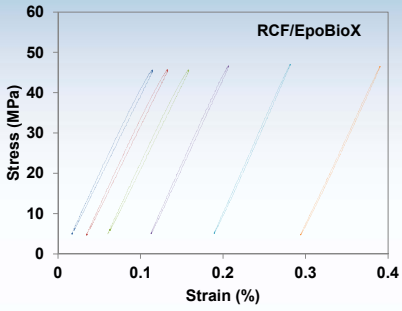
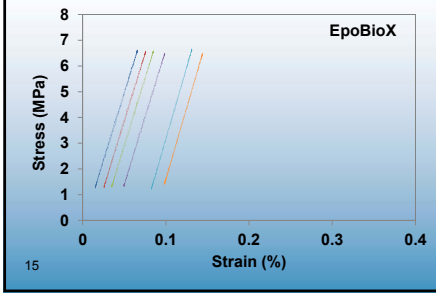
RESULTS

Fatigue Cycles





1st Cycle
10th
100th
1000th
10000th
100000th



1st Cycle
10th
100th
1000th
10000th
16000th

STRESS LEVEL	
EpoBioX	$0.15\sigma_{UT}$
RCF/EpoBioX	$0.20\sigma_{UT}$
GF/EpoBioX	$0.25\sigma_{UT}$

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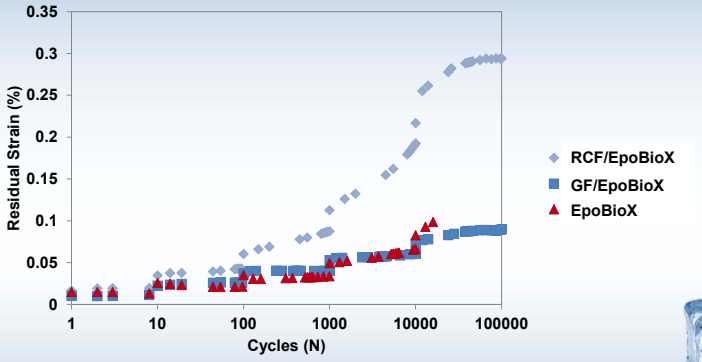
RESULTS

Accumulation of Residual Strain



$\varepsilon_{Residual}$ %						
N_{cyc}	1	10	100	1000	10000	100000
RCF/EpoBioX	0,02	0,03	0,06	0,10	0,21	0,33
GF/EpoBioX	0,01	0,03	0,04	0,05	0,07	0,09
EpoBioX	0,02	0,03	0,03	0,04	0,08	Failed

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CONCLUDING REMARKS

- EpoBioX performs as well as Epoxy.
- Polymers are almost unaffected by moisture, whereas fibers show significant sensitivity.
- Tribest has poor performance and is most affected by moisture; nevertheless Tribest-based composites show decent properties.
- Due to sensitivity of fibers to moisture, composites properties are drastically reduced when exposed to high RH.
- At fairly low stress, none of the materials showed large degradation of stiffness in fatigue.
- No difference is detected between plasticity conditioned and non conditioned materials.

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FUTURE WORK

- ❑ Fatigue of UD composites at higher stresses
- ❑ Fatigue of multi-axial laminates
- ❑ Fiber treatment to protect from humidity
- ❑ Modelling fatigue behaviour

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