

Les composites polymères : MSE340-2024

Introduction-**Conclusions**

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Matériaux, procédés, propriétés

CALENDRIER	MSE 340 COMPOSITES			
	TP composites	Cours composites		
	lu 8-12h	lu 14-16h	BC01	
lundi, 9 septembre 2024	Organisation	Cours	Intro aux composites	PEB/VM
lundi, 16 septembre 2024	férié	férié		
lundi, 23 septembre 2024		Cours	Constituants des composites	VM/PEB
lundi, 30 septembre 2024	TP	Cours	Bases théoriques de la mise en œuvre des composites	VM
lundi, 7 octobre 2024		Cours	Procédés de mise en œuvre des composites	VM
lundi, 14 octobre 2024	TP	Cours	Procédés de mise en œuvre des composites	VM
lundi, 21 octobre 2024				
lundi, 28 octobre 2024	TP	Cours	Intro à la mécanique des composites	PEB
lundi, 4 novembre 2024		Cours	Micromécanique	PFR
lundi, 11 novembre 2024	TP	Cours		
lundi, 18 novembre 2024		Cours		
lundi, 25 novembre 2024	TP	Cours		
lundi, 2 décembre 2024		Cours		
lundi, 9 décembre 2024	TP	Cours		
lundi, 16 décembre 2024		Cours		
EVALUATION: 1/3 rapports des TP, 2/3 examen oral				

Learning outcomes

A la fin de ce cours l'étudiant doit être capable de:

- Appliquer les méthodes de calculs pour déterminer les propriétés mécaniques des matériaux anisotropes
- Dimensionner des structures en composites (simples)
- Proposer des matériaux en choisissant leur composition et les procédés de fabrication pour une application donnée
- Comparer les matériaux composites entre eux
- Discuter les tests de caractérisation des composites
- Distinguer les avantages et limitations des procédés.
- Dialoguer avec des professionnels d'autres disciplines.
- Utiliser les outils informatiques courants ainsi que ceux spécifiques à leur discipline.

5 TPs sur la mise en oeuvre et les propriétés des composites
Examen oral en Janvier

TP



Constituants

Renforts

B: Flexibilité

Flexion d'une poutre cylindrique:

E module, I moment d'inertie

$$I = \pi d^4 / 64$$

R rayon de courbure
et M moment de flexion

$$R = EI / M = E \pi d^4 / 64 M$$

Donc R est proportionnel à d^4 .

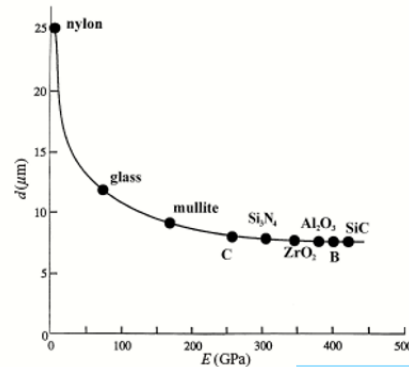


Figure 1
Diameter of various fibers with a flexi of a 25 μm diameter nylon fiber. Given diameter, it is possible to produce, in flexible fiber from a polymer, a metal,

Les matrices polymères

Thermodurcis

- Avantages
- + Résines liquides à T ambiante
 - + Facilité de mise en oeuvre (EP, UP)
 - + Durcissement entre 5 et 180C (EP)
 - + Prix raisonnable
 - + Grande variété de formulation possibles
 - + Bonne adhésion aux fibres
 - + Amorphe

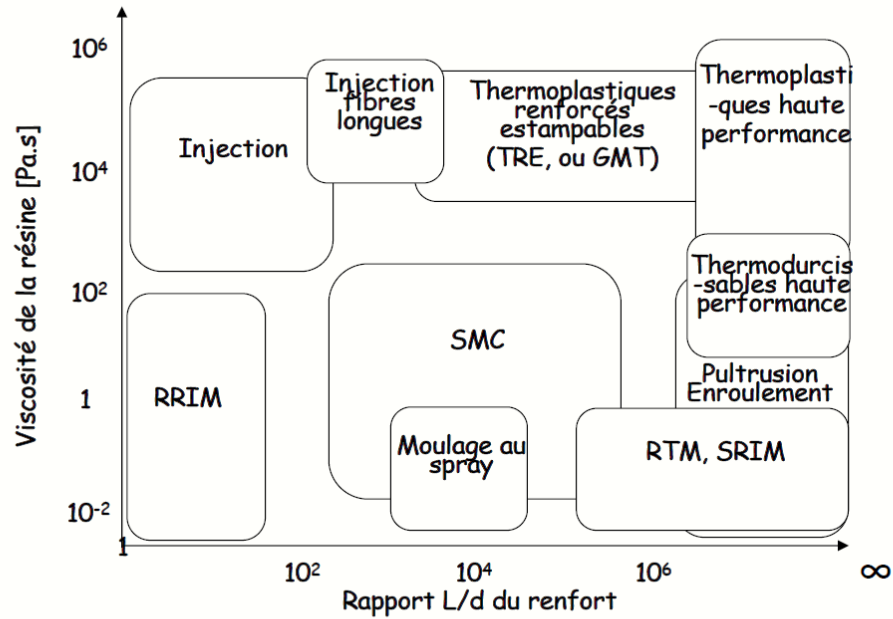
- Inconvénients
- Volatilité, toxicité, allergies
 - Résistance à l'humidité
 - Résistance aux chocs
 - Contrôle de la réaction chimique

Thermoplastiques

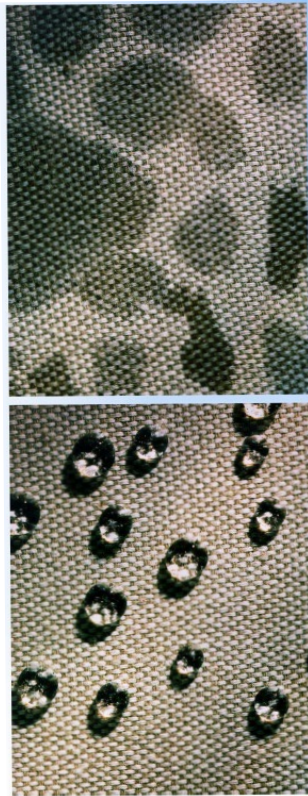
- Avantages
- + Mise en oeuvre rapide, par élévation de T
 - + Procédés de mise en oeuvre des thermoplastiques utilisables avec les fibres courtes
 - + Bonne résistance à l'humidité
 - + Recyclage aisé

- Inconvénients
- Souvent peu résistantes à la T
 - Retrait au moulage (matrices s-c)
 - Mauvaise résistance chimique
 - Adhésion aux fibres souvent problématique
 - Propriétés mécaniques faibles, fluage

Mise en oeuvre

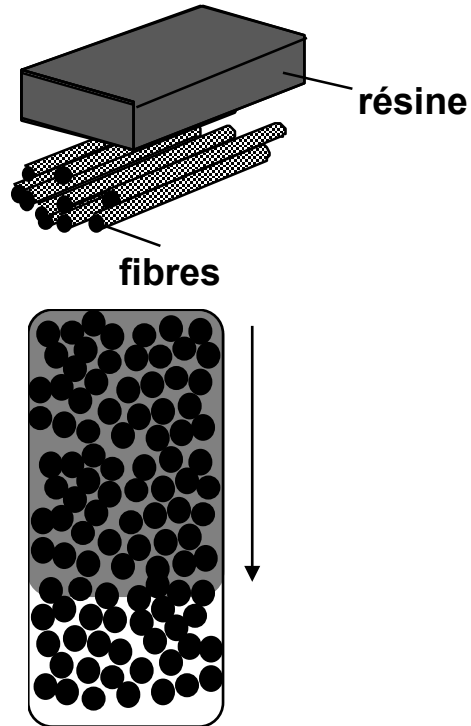


Les phénomènes



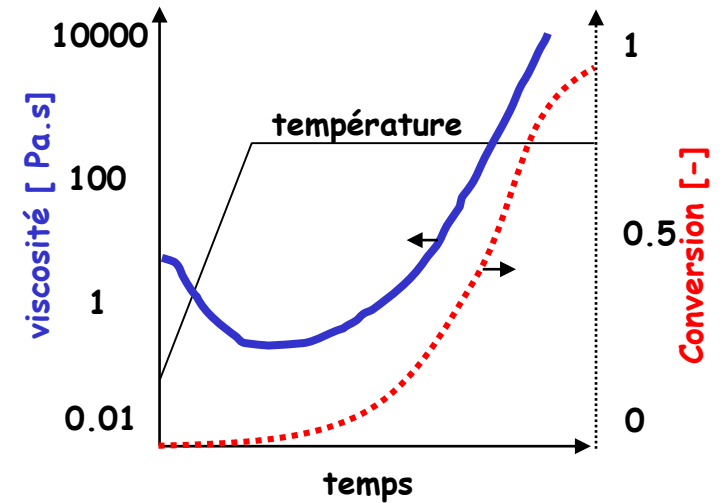
Mouillabilité
Tensions de surface

...



Imprégnation
Perméabilité

....



Transformation de la matrice

? mise en oeuvre

Quel polymère et quelles fibres pour un pare-chocs de voiture ?

Décrivez la mise en œuvre par SMC ?

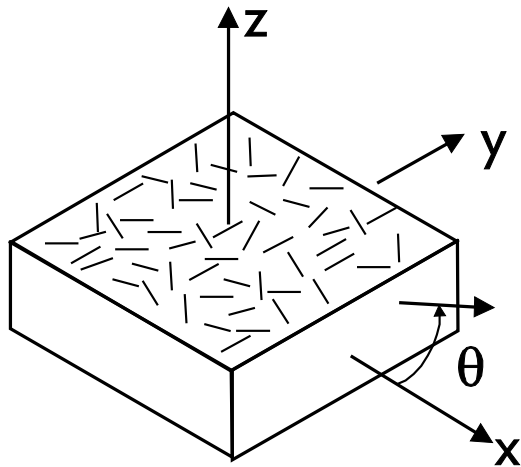
Citez 3 résines thermodurcissables ?

Comment pouvons nous déterminer la perméabilité ?

...

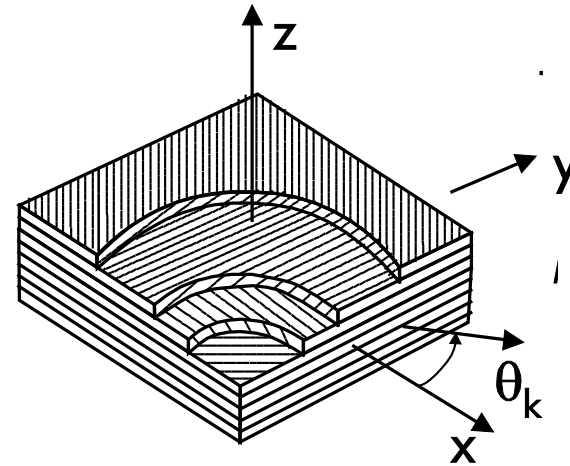
Mécanique des composites : propriétés

Composites à fibres courtes



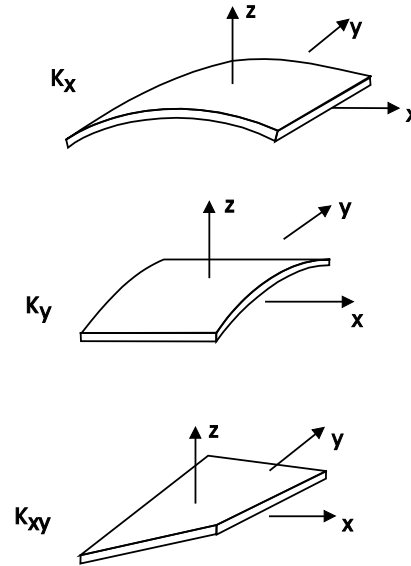
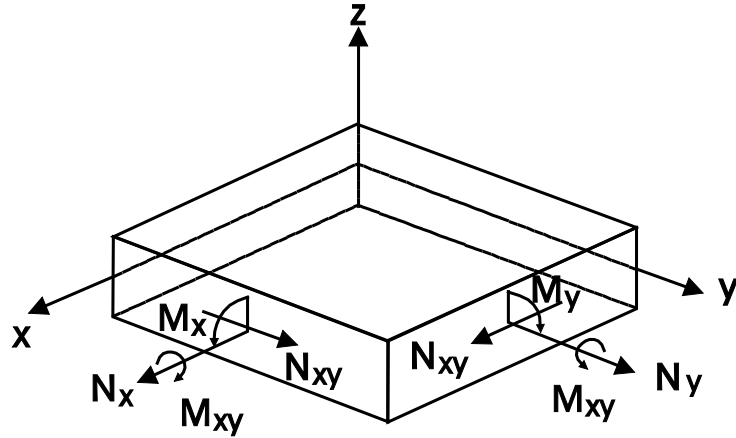
$$E_I = E_f V_f \left[1 - \frac{\tanh(\beta l/2)}{\beta l/2} \right] + E_m V_m$$

Stratifiés

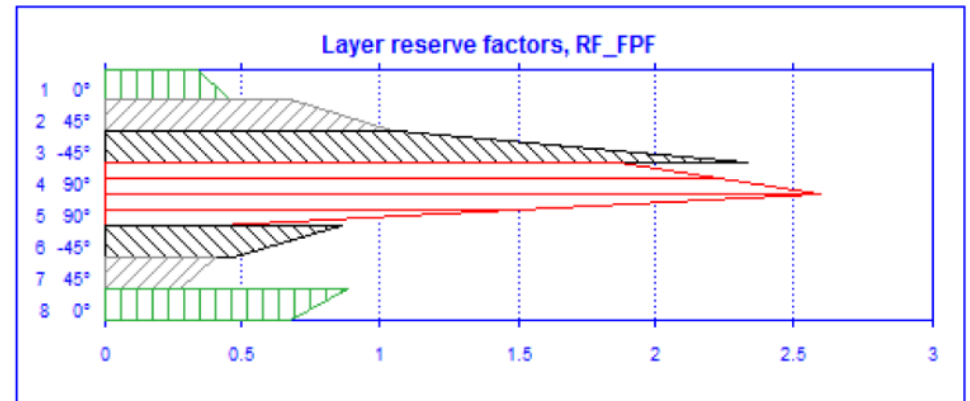


$$E_x = \frac{A_{11} A_{22} - A_{12}^2}{h A_{22}}$$

Résistance des matériaux composites



$$\begin{bmatrix} N \\ M \end{bmatrix} = \begin{bmatrix} A & B \\ B & D \end{bmatrix} \begin{bmatrix} \varepsilon^0 \\ \kappa \end{bmatrix}$$



? propriétés des anisotropes

Comment calculer le module transverse
d'un composite unidirectionnel ?

Comment se déforme un stratifié
sous l'effet d'un moment de flexion ?

Pourquoi les contraintes sont différentes
dans chaque pli d'un stratifié ?

Comment augmenter un Reserve Factor ?

Exercices

Exo7: en augmentant le nombre de strates, A ne change pas, B diminue. Calculs avec des épaisseurs égales des plis, ? quid si avec des plis d'épaisseurs différentes

The diagram shows a 5-layer laminate with a total thickness of 1.0. The layers are numbered 1 to 5 from bottom to top. The z-axis is vertical, with z=0 at the center. The thickness of each layer is 0.2. The orientation of each layer is given in degrees.

Layer	Thickness	Orientation
1	0.2	0°
2	0.2	90°
3	0.2	0°
4	0.2	90°
5	0.2	0°

Below the diagram, the thickness of each layer is calculated as the difference between the z-coordinates of its top and bottom surfaces:

- 1 0° : $-0,375 - (-0,5) = 0,125$
- 2 90° : $-0,125 - (-0,375) = 0,25$
- 3 0° : $0,125 - (-0,125) = 0,25$
- 4 90° : $0,375 - (0,125) = 0,25$
- 5 0° : $0,5 - (0,375) = 0,125$

The final equation for the stiffness matrix is:

$$A_{ij} = \frac{1}{2} \overline{Q}_{ij/0^\circ} + \frac{1}{2} \overline{Q}_{ij/90^\circ}$$

Exercices

Cours MSE 340 Composites Polymères 2024, Exo B avec ESACOMP : résistances, critères de rupture Exemples de déterminations de la rupture du premier pli et de l'optimisation des facteurs de réserve pour éviter les ruptures. La même approche est utilisée pour valider vos choix de matériaux et de structure du stratifié pour votre bouteille sous pression et votre snowboard.

Laminate FPF analysis

Laminate : C 045905
 Modified: Sun Nov 11 17:28:27 2012
 Lay-up: (0a)45a(-45a)90a)SE h = 1.84 mm

Ply	1	E_1	E_2	G_12	nu_12	G_31	G_23
	mm	GPa	GPa	GPa	GPa	GPa	GPa
a E.EpoxyUD-23029950	0.23	30	9	3.6	0.3	3.6	3.46154

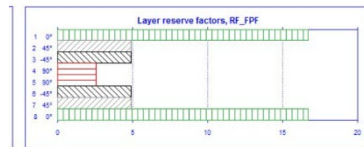
Load: 5kN sur 10 cm
 Modified: Sun Nov 11 18:15:35 2012
 Type: Forces and moments (Var.E)

N_x = 50000 N/m N_y = 0 N/m
 M_x = 0 N/m M_y = 0 N/m
 Q_x = 0 N/m Q_y = 0 N/m

Factor of safety: FoS_N = 1
 Failure criterion: Tsai-Wu, Max strain, Von Mises, Out-of-plane shear, Out-of-plane s (UD, non-UD, homogeneous, honeyc, core, foam/other core, adhes
 Failure crit. param: Tsai-Wu F_12* = 0.5
 Stress/strain recovery: layer top/bottom

Laminate reserve factors

FFP Mode FFP-only Mode Crit. layers ILS Crit. interf.
 RF = 2.00 2i 2.00 2i (90°) - -



Layer reserve factors - FFP

Ply	theta	RF
1	a 0	1 3.1674 11
	b	16.74
2	a 45	1 2.495 2i
	b	4.95
3	a -45	1 2.495 2i
	b	4.95
4	a 90	1 2.260 2i
	b	2.60
5	a 90	1 1.2.60 2i
	b	2.60
6	a -45	1 2.495 2i
	b	4.95
7	a 45	1 2.495 2i
	b	4.95
8	a 0	1 3.1674 11
	b	16.74

Laminate FPF analysis

Laminate : C 045905
 Modified: Sun Nov 11 17:28:27 2012
 Lay-up: (0a)45a(-45a)90a)SE h = 1.84 mm

Ply	1	E_1	E_2	G_12	nu_12	G_31	G_23
	mm	GPa	GPa	GPa	GPa	GPa	GPa
a E.EpoxyUD-23029950	0.23	30	9	3.6	0.3	3.6	3.46154

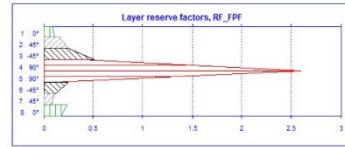
Load: 5kN sur 10 cm et 10000Nm sur 25 cm
 Modified: Sun Nov 11 19:20:02 2012
 Type: Forces and moments (Var.E)

N_x = 50000 N/m N_y = 2000 N/m
 M_x = 0 N/m M_y = 0 N/m
 Q_x = 0 N/m Q_y = 0 N/m

Factor of safety: FoS_N = 1
 Failure criterion: Tsai-Wu, Max strain, Von Mises, Out-of-plane shear, Out-of-plane s (UD, non-UD, homogeneous, honeyc, core, foam/other core, adhes
 Failure crit. param: Tsai-Wu F_12* = 0.5
 Stress/strain recovery: layer top/bottom

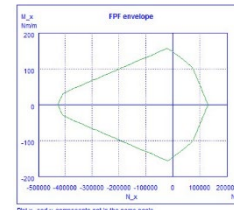
Laminate reserve factors

FFP Mode FFP-only Mode Crit. layers ILS Crit. interf.
 RF = 0.07 2i 0.07 2i 7(45°) - -



Layer reserve factors - FFP

Ply	theta	RF
1	a 0	1 2.00 10/2i
	b	0.11
2	a 45	1 5.0 18 a
	b	0.25
3	a -45	1 7.0 25 a
	b	0.51
4	a 90	1 8.0 40 2c
	b	2.80
5	a 90	1 3.260 2i
	b	0.11
6	a -45	1 4.0 25 21a
	b	0.13
7	a 45	1 1.0 11 2i
	b	0.07
8	a 0	1 6.0 23 1i
	b	0.17



Failure criterion: Tsai-Wu, Max strain, Von Mises, Out-of-plane shear, Out-of-plane s (UD, non-UD, homogeneous, honeyc, core, foam/other core, adhes)
 Failure crit. param: Tsai-Wu F_12* = 0.5
 Stress/strain recovery: layer top/bottom

Laminate FPF analysis

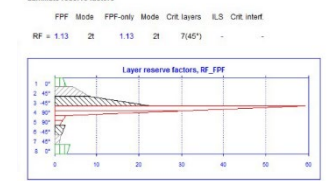
Laminate : 045905 8mm
 Modified: Sun Nov 11 22:01:22 2012
 Lay-up: ((0a)4(-45a)4(-45a)4(90a)4)SE h = 7.36 mm

Ply	1	E_1	E_2	G_12	nu_12	G_31	G_23
	mm	GPa	GPa	GPa	GPa	GPa	GPa
a E.EpoxyUD-23029950	0.23	30	9	3.6	0.3	3.6	3.46154

Load: 5kN sur 10 cm et 10000Nm sur 25 cm
 Modified: Sun Nov 11 22:05:53 2012
 Type: Forces and moments (Var.E)

N_x = 50000 N/m N_y = 2000 N/m
 M_x = 0 N/m M_y = 0 N/m
 Q_x = 0 N/m Q_y = 0 N/m

Factor of safety: FoS_N = 1
 Failure criterion: Tsai-Wu, Max strain, Von Mises, Out-of-plane shear, Out-of-plane s (UD, non-UD, homogeneous, honeyc, core, foam/other core, adhes
 Failure crit. param: Tsai-Wu F_12* = 0.5
 Stress/strain recovery: layer top/bottom



Layer reserve factors - FFP

Ply	theta	RF
1	a 0	1 4.150 10/2i
	b	2.74
2	a 45	1 7.443 a
	b	8.22
3	a -45	1 8.899 a
	b	22.77
4	a 90	1 5.5919 2i
	b	2.80
5	a 90	1 2.260 2i
	b	1.23
6	a -45	1 3.254 2i
	b	1.71
7	a 45	1 1.52 2i
	b	1.13
8	a 0	1 3.68 1i
	b	2.81

Laminate FPF analysis

Laminate : 045905 8mm
 Modified: Sun Nov 11 22:01:22 2012
 Lay-up: ((0a)4(-45a)4(-45a)4(90a)4)SE h = 7.36 mm

Ply	1	E_1	E_2	G_12	nu_12	G_31	G_23
	mm	GPa	GPa	GPa	GPa	GPa	GPa
a E.EpoxyUD-23029950	0.23	30	9	3.6	0.3	3.6	3.46154

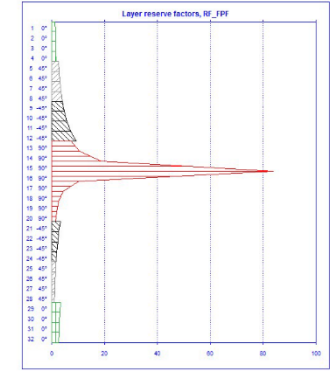
Load: 5kN sur 10 cm et 10000Nm sur 25 cm
 Modified: Sun Nov 11 22:05:53 2012
 Type: Forces and moments (Var.E)

N_x = 50000 N/m N_y = 2000 N/m
 M_x = 0 N/m M_y = 0 N/m
 Q_x = 0 N/m Q_y = 0 N/m

Factor of safety: FoS_N = 1
 Failure criterion: Tsai-Wu, Max strain, Von Mises, Out-of-plane shear, Out-of-plane s (UD, non-UD, homogeneous, honeyc, core, foam/other core, adhes
 Failure crit. param: Tsai-Wu F_12* = 0.5
 Stress/strain recovery: layer top/bottom

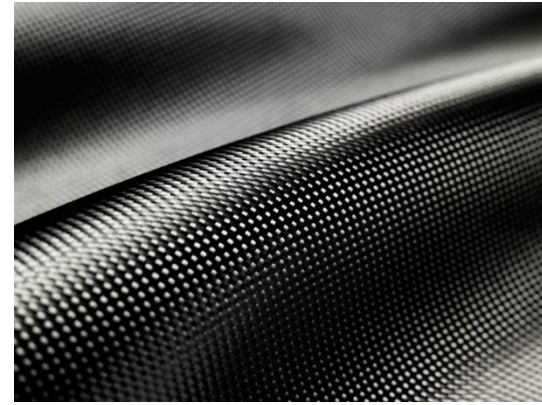
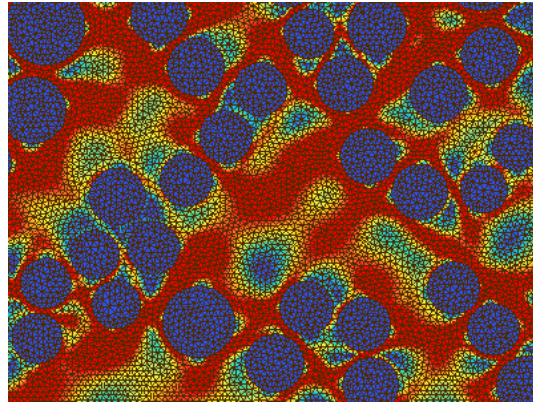
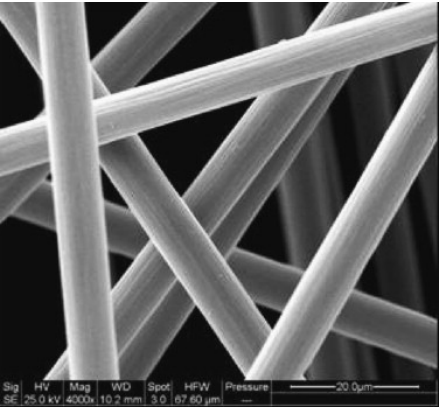
Laminate reserve factors

FFP Mode FFP-only Mode Crit. layers ILS Crit. interf.
 RF = 1.11 2i 1.11 2i 28(45°) - -



Ply	theta	RF
1	a 0	1 4.150 10/2i
	b	1.44
2	a 45	1 5.144 10/2i
	b	1.54
3	a 0	1 7.154 10/2i
	b	1.67
4	a 0	1 9.167 10/2i
	b	1.81
5	a 45	1 15.271 a
	b	2.97
6	a 45	1 19.297 a
	b	3.29
7	a -45	1 22.329 a
	b	3.69
8	a 45	1 23.369 a
	b	4.92
9	a -45	1 24.425 a
	b	5.84
10	a -45	1 26.492 a
	b	7.18
11	a -45	1 27.554 a
	b	7.18
12	a -45	1 28.718 a
	b	9.32
13	a 90	1 29.743 2c
	b	10.68
14	a 90	1 31.1068 2c
	b	15.97
15	a 90	1 32.1597 2c
	b	83.52
16	a 90	1 33.832 2i
	b	10.36
17	a 90	1 25.1938 2i
	b	4.36
18	a 90	1 16.436 2i
	b	2.70
19	a 90	1 11.276 2i
	b	8.202 2i
20	a 90	1 8.202 2i
	b	1.59
21	a -45	1 17.344 21a
	b	2.85
22	a -45	1 13.285 21a
	b	2.12
23	a -45	1 12.243 21a
	b	2.12
24	a -45	1 10.212 21a
	b	1.88
25	a 45	1 6.162 2i
	b	1.31
26	a 45	1 3.145 2i
	b	1.11
27	a 45	1 2.131 2i
	b	1.20
28	a 45	1 1.20 2i
	b	1.11
29	a 0	1 21.354 1i
	b	3.38
30	a 0	1 20.320 1i
	b	3.06
31	a 0	1 18.306 1i
	b	2.86
32	a 0	1 14.286 1i
	b	2.69

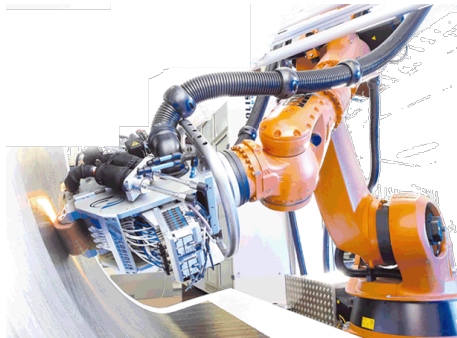
www.....composites.....



www.reinforcedplastics.com

www.onera.fr

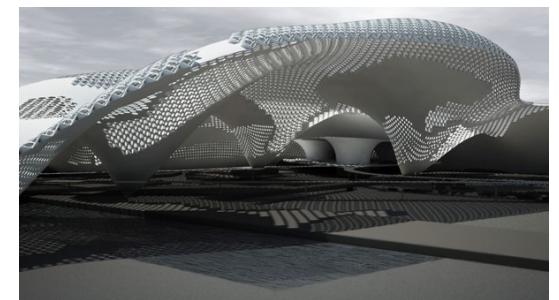
blog.motorlegend.com



www.coriolis-composites.com

Boeing

BMW i8 automobile.challenges



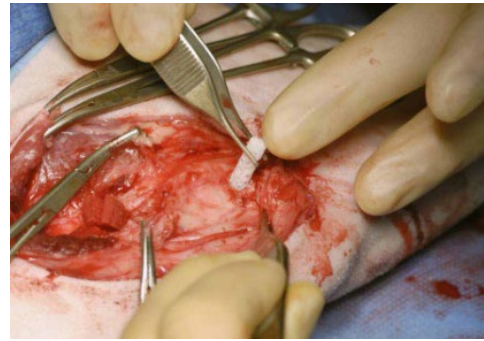
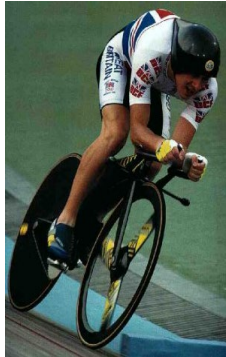
www.decision.ch

Samsonite zedomax.com

Hublot

www.evolo.us

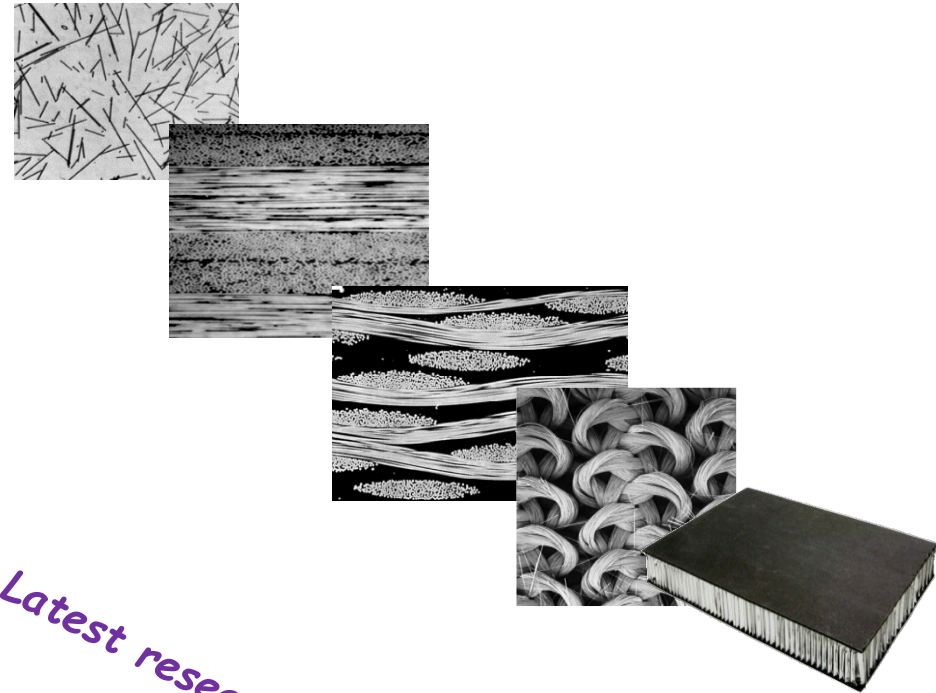
Composite materials?



Your composite product...

Ready for the future...

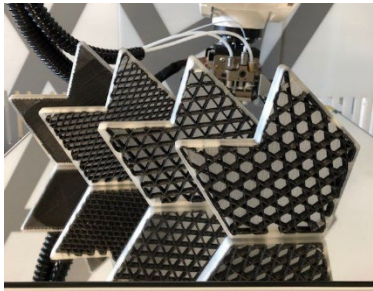
- Introduction aux composites
- Constituants
- Théorie et procédés de mise en œuvre
- Micromécanique, Macromécanique
- Illustrations de choix de matériaux, de mise en œuvre, de conception...
- Quelques principes de recyclage
- Exercices
- Bases pour le cours MSE 440 de Master
 - Sandwich structures and textiles composites
 - Structural design and joining with composites
 - Towards sustainable composites
 - Biocomposites for biomed, sport...
 - Cost modelling-a tool for sustainable innovation
 - Smart composites
 - Nanocomposites



*Latest research, innovation and...
...your composite products*

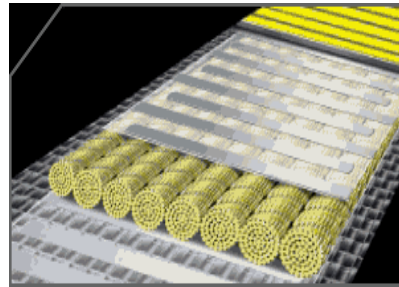
R&D&A

3D printing

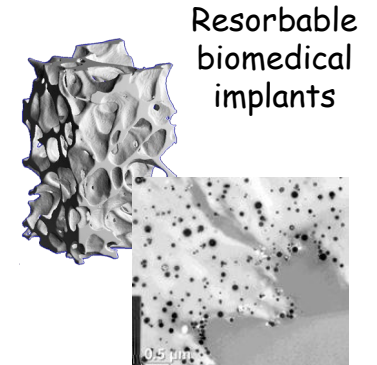


Anisoprint

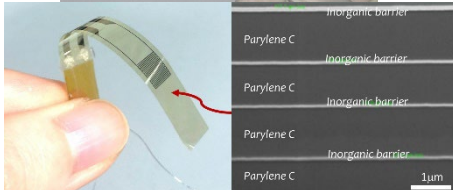
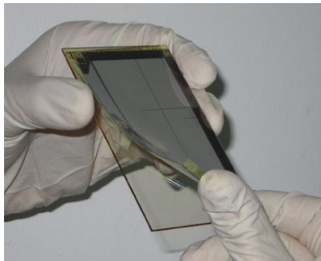
Functional composites



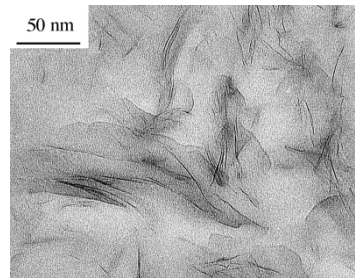
Biocomposites



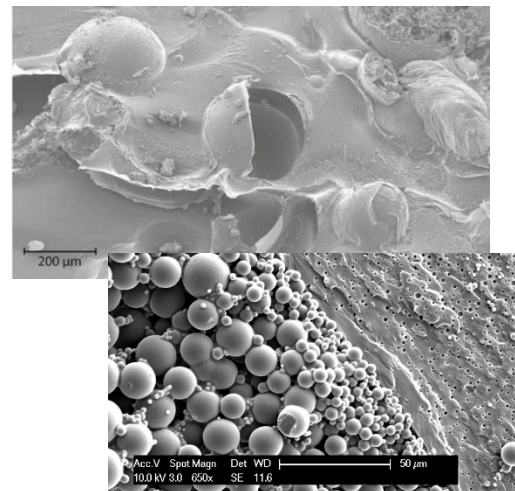
Thin films and micro devices



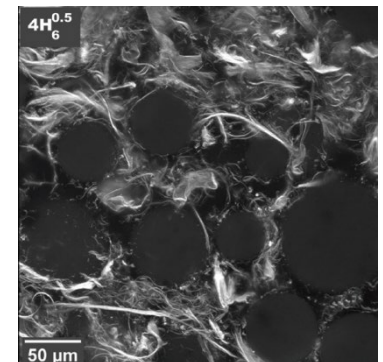
Nanocomposites



Self-healing composites



Hydrogel composites



Your composite product...

Durable smartphone case made of recycled composites



Composites Technology

Driver gloves for Formula 1

The temperature elevation for a heat flux of 10,000 W/m² during 30s was recorded. The result obtained on our glove is shown in Figures 3c and 3d and is compared to the initial Formula 1 glove in Figures 3a and 3b below.

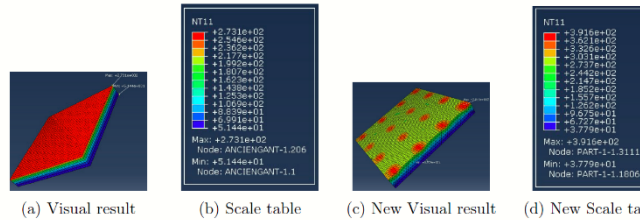


Figure 3: Results of the Abaqus simulation for a reference fabric and for the new product

Composite photovoltaic blinds

Composite technologies- MSE-440 -Team 5



Ecofriendly shelters

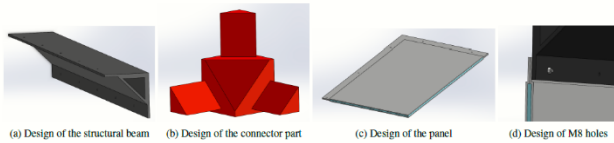
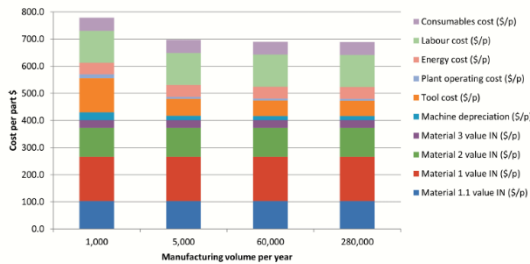


Figure 1: Design of main elements of the house



Piezochromatic composite in hydrogen pressure vessels

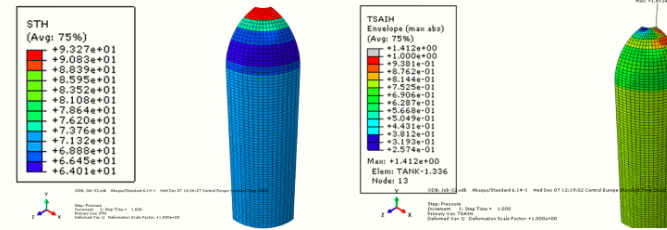


Figure 5. Final thicknesses of fibers on the pressure vessel [mm]. Figure 6. Tsai Hill Failure criterion for envelope and weakest ply.

Composite Greenhouse



Figure 5: 3D views of the greenhouse structure design

Ergonomic air tank



Fig. 1. Free-molded ergonomic portable compressed air tank

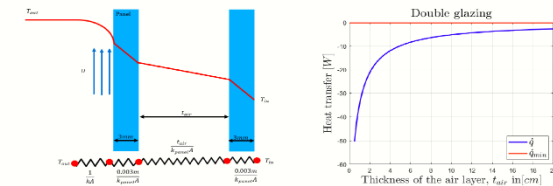
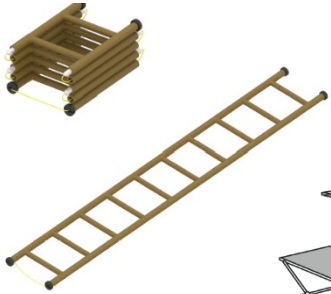


Figure 1: Sketch of the double glazing case. There is only convection outside and conduction inside the panel and in the air trapped between the two panels. Between these panels, convection is neglected because the system is airtight

Figure 2: Heat transfer in function of the thickness of the air layer between the two panels. The red line represent the minimum heat transfer.

Your composite product...

Composite ladder



Camping kit

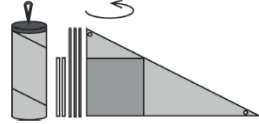


Figure 1: Sketch kit folded

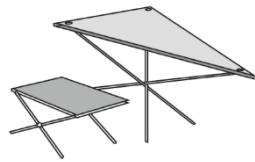
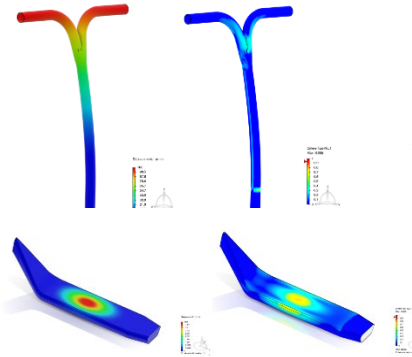
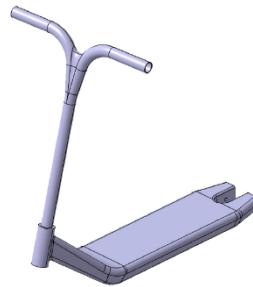
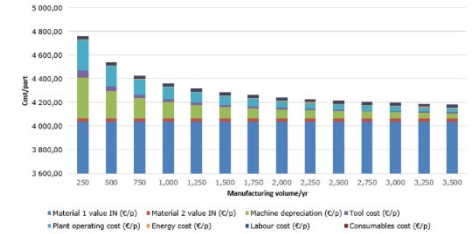


Figure 2: Sketch kit unfolded

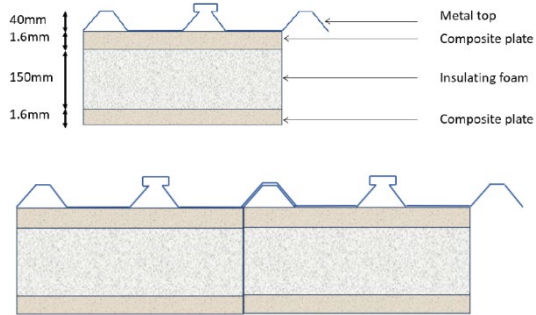
Rental Electric Scooter - Flax fibers deck & steering pole



Cost per E-scooter (CHF/p)



Roof panels



Biodegradable flower pots

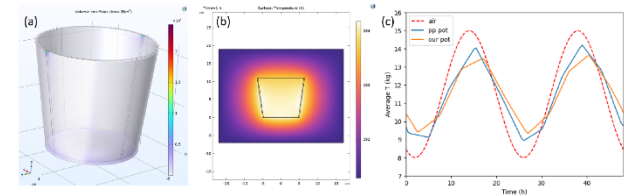
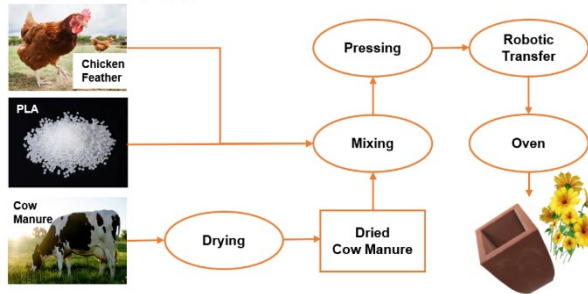
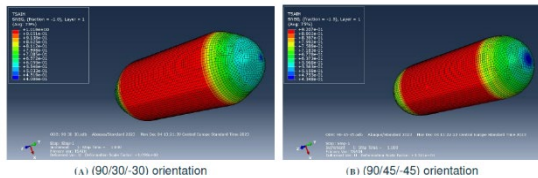
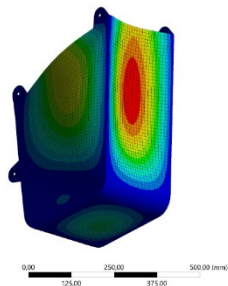


Figure 1. (a) The loading test on flower pots. (b) Time-dependent thermal simulation setup. (c) Temperature variance in the center of the pot during 2 days. The red dash line is the reference air temperature in the environment where the flower pot is put.

Oxygen cylinders



Battery tray for electric motorcycle



Composite longboard

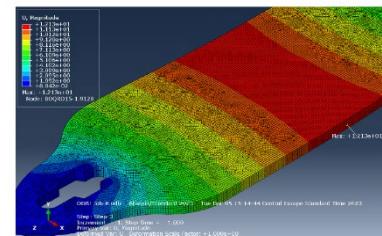


Figure 3: Deflection of the board under load

Examen

- MSE 340 Composites: 1/3 TP + 2/3 examen
- Oral le 30 et 31 Janvier
- 5 min de préparation et 15 minutes de réponses
- 3 questions: Constituants/Mise en œuvre/Mécanique

- Liste de passage (Moodle, fichier partagé...)

- <https://docs.google.com/spreadsheets/d/1vMpbdes4FIINZgwfZNScfrZTd3DPYVLIwxQKzwLknu0/edit?gid=0#gid=0>

- Révision : le résumé, les exos, les questions