Mécanique des composites

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Mécanique des composites

Micro et macromécanique

Tests mécaniques

Endommagement et rupture

CADFEM

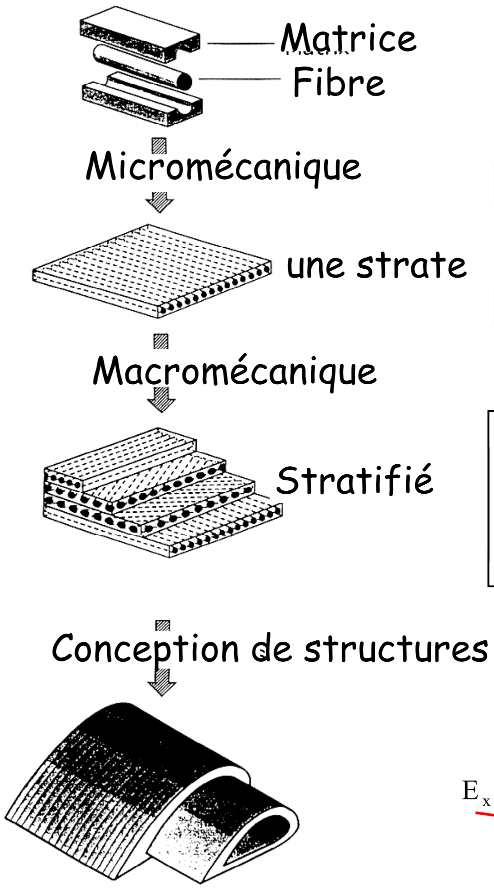
Applications

Les stratifiés

Structures sandwich

Composites textiles

De la fibre à la structure



$$E_1 = E_f V_f + E_m (1 - V_f) \qquad P = \frac{P_m (1 + \xi \chi V_f)}{1 - \chi V_f}$$

$$Q_{11} = \frac{E_1}{(1 - \nu_{12}\nu_{21})}$$

$$\overline{Q}_{11} = m^4 Q_{11} + 2m^2 n^2 (Q_{12} + 2Q_{66}) + n^4 Q_{22}$$

$$\begin{bmatrix} \sigma_1 \\ \sigma_2 \\ \tau_{12} \end{bmatrix} = \begin{bmatrix} Q_{11} & Q_{12} & 0 \\ Q_{12} & Q_{22} & 0 \\ 0 & 0 & Q_{66} \end{bmatrix} \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \gamma_{12} \end{bmatrix} \qquad \begin{bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{bmatrix} = \begin{bmatrix} \overline{Q}_{11} & \overline{Q}_{12} & \overline{Q}_{16} \\ \overline{Q}_{12} & \overline{Q}_{22} & \overline{Q}_{26} \\ \overline{Q}_{16} & \overline{Q}_{26} & \overline{Q}_{66} \end{bmatrix} \begin{bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{bmatrix}$$

$$A_{ij} = \sum_{k=1}^{N} (\overline{Q}_{ij})_k (z_k - z_{k-1})$$

$$\begin{bmatrix} N_x \\ N_y \\ N_{xy} \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} & A_{16} \\ A_{12} & A_{22} & A_{26} \\ A_{16} & A_{26} & A_{66} \end{bmatrix} \begin{bmatrix} \varepsilon_x^0 \\ \varepsilon_y^0 \\ \gamma_{xy}^0 \end{bmatrix} + \begin{bmatrix} B_{11} & B_{12} & B_{16} \\ B_{12} & B_{22} & B_{26} \\ B_{16} & B_{26} & B_{66} \end{bmatrix} \begin{bmatrix} K_x \\ K_y \\ K_{xy} \end{bmatrix}$$

$$\begin{bmatrix} \varepsilon_x^0 \\ \varepsilon_y^0 \\ \gamma_{xy}^0 \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & 0 \\ a_{12} & a_{22} & 0 \\ 0 & 0 & a_{66} \end{bmatrix} \left\{ \begin{bmatrix} N_x \\ N_y \\ N_{xy} \end{bmatrix} + \begin{bmatrix} N_x^T \\ N_y^T \\ 0 \end{bmatrix} \right\}$$

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

$$\begin{bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{bmatrix} = \begin{bmatrix} \frac{1}{E_x} & -\frac{\nu_{xy}}{E_x} & 0 \\ -\frac{\nu_{yx}}{E_y} & \frac{1}{E_y} & 0 \\ 0 & 0 & \frac{1}{G_{xy}} \end{bmatrix} \begin{bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{bmatrix}$$

Mx élastiques
Porosité nulle/minimale
Interfaces fibre-matrice parfaites/optimales

Orientations des fibres

Orthotropie
Contraintes planes

Adhésion entre plis parfaite/optimale

Symétries d'empilement
Effets de couplage

Cas de charges
Propriétés effectives
Mécanique des matériaux

Exemples

Orientation des fibres

Et si j'augmente le nombre de plis
tout en gardant la même épaisseur ?

Pourquoi des plis à 45 ?

Les hybrides

...

Contraintes et Rupture

Mécanique des matériaux

Contraintes principales

Critères de rupture

Rupture du premier pli

Rupture du composite

Endommagement

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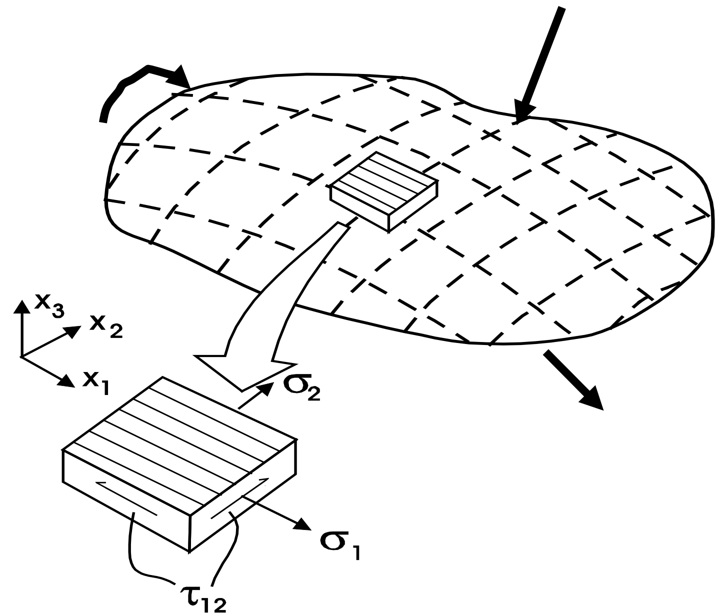
Efforts,contraintes et contraintes principales

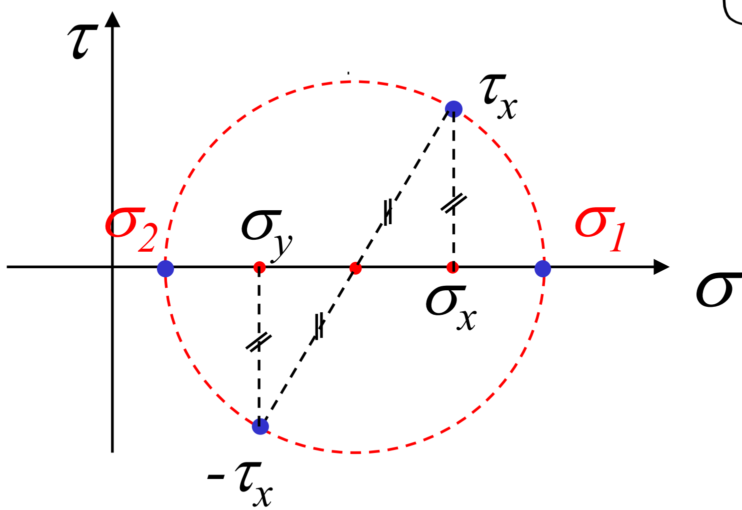
$$\sigma = \frac{N}{S}$$

$$\sigma = \frac{M}{I_y} \cdot z$$

$$\frac{1}{r_c} = \frac{M}{E \cdot I}$$

$$\tau = \frac{M_t}{I_P} \cdot r$$





Idéalement il faudrait orienter les fibres selon les isostatiques.

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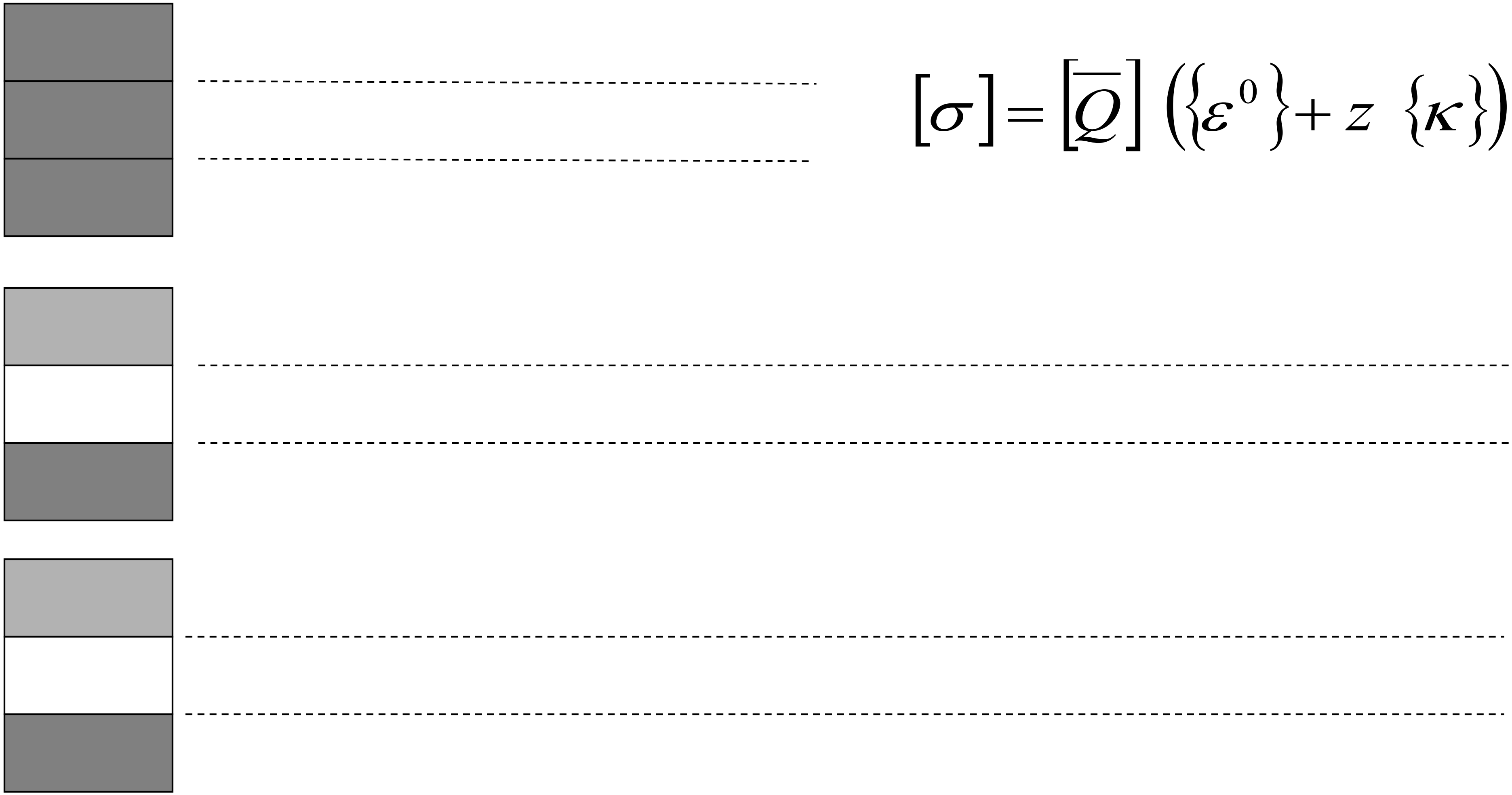
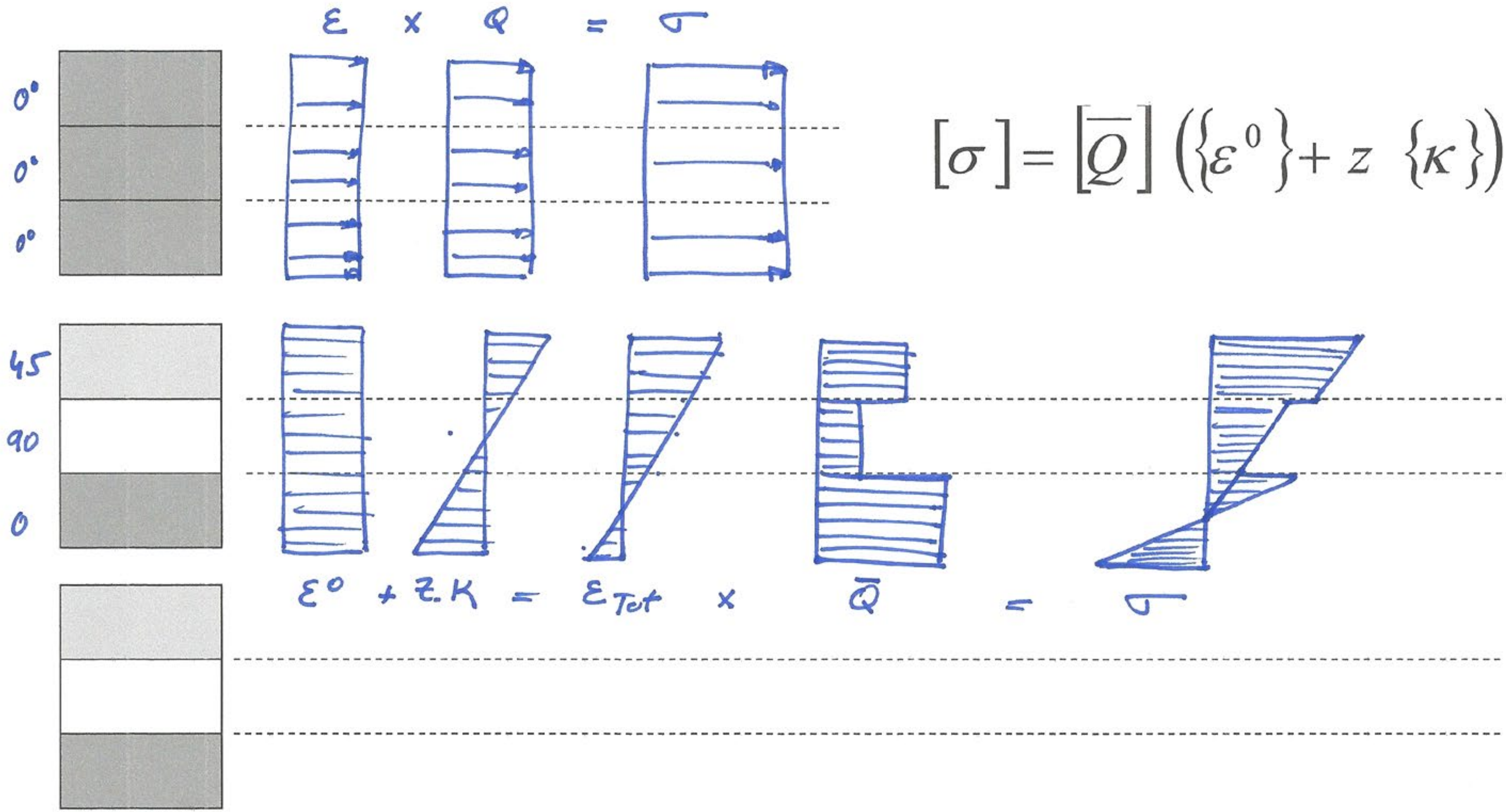
Contraintes dans les stratifiés anisotropes



$$[\sigma] = [\overline{Q}]\left(\{\varepsilon^0\} + z\ \{\kappa\}\right)$$

Contraintes dans les stratifiés anisotropes



$$[\sigma] = [\overline{Q}]\left(\{\varepsilon^0\} + z\ \{\kappa\}\right)$$

Résistances ultimes

Laminate FPF analysis

Laminate : C 04590S
Modified : Sun Nov 11 17:28:27 2012

Lay-up : (0a/+45a/-45a/90a)SE h = 1.84 mm

Ply		t	E_1	E_2	G_12	nu_12	G_31	G_23
		mm	GPa	GPa	GPa		GPa	GPa
a	E;Epoxy;UD-.230/299/50	0.23	38	9	3.6	0.3	3.6	3.46154

	X_t	X_c	Y_t	Y_c	S	R	Q	X_eps,t	X_eps,c	Y_eps,t	Y_eps,c	S_
	MPa	MPa	MPa	MPa	MPa	MPa	MPa	%	%	%	%	
a	930	570	33	110	70	70	41.5385	2.44737	1.5	0.366667	1.22222	1.94

Load : 5kN10cm Mx125sur25cm
Modified : Sun Nov 11 21:02:20 2012
Type : Forces and moments (Var.;E)

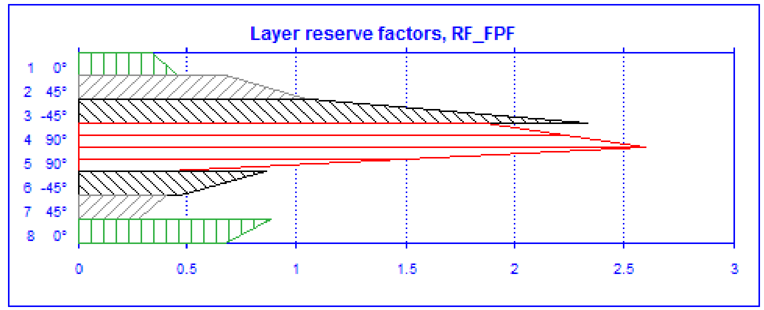
N_x =	50000 N/m	M_x =	500 Nm/m
N_y =	0 N/m	M_y =	0 Nm/m
N_xy =	0 N/m	M_xy =	0 Nm/m

Q_x = 0 N/m
Q_y = 0 N/m

Factor of safety : FoS^v = 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; adhe
Failure crit. param. : Tsai-Wu F_12*=-0.5
Stress/strain recovery : layer top/bottom

Laminate reserve factors

	FPF	Mode	FPF-only	Mode	Crit. layers	ILS	Crit. interf.
RF =	0.28	2t	0.28	2t	7(45°)	-	-



Layer reserve factors - FPF

	Ply	theta °			RF	
1	a	0	t	2.	0.34	1c/2t
			b		0.45	
2	a	45	t	6.	0.68	s
			b		1.05	
3	a	-45	t	7.	1.06	s
			b		2.33	
4	a	90	t	8.	1.86	2c
			b		2.60	
5	a	90	t	3.	2.60	2t
			b		0.40	
6	a	-45	t	4.	0.86	2t/s
			b		0.47	
7	a	45	t	1.	0.40	2t
			b		0.28	
8	a	0	t	5.	0.89	1t
			b		0.67	

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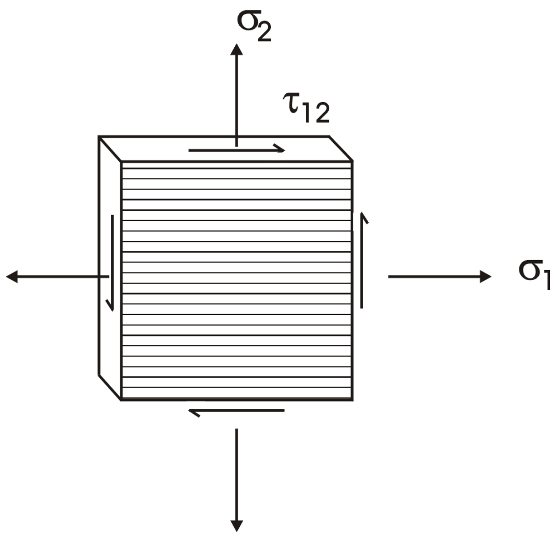
Résistances ultimes



	V_f	$\sigma^T_{u,1}$	$\sigma^T_{u,2}$	$\sigma^C_{u,1}$	$\sigma^C_{u,2}$	τ_u
carbone / époxy (AS/3501)	0.60	1448	48	1172	248	62
Kevlar 49 /époxy	0.60	1380	27	276	65	60
verre-E / époxy (scotch ply 1002)	0.45	1100	28	620	138	83

Les normes

Table 2 Typical mechanical properties reported on data sheets

Property	Test method	Test description	Usefulness for design purposes
Tensile strength	ASTM D 638	Property reports the stress in a standard specimen at the specified point on the stress-strain curve. Value reported could be yield or ultimate.	Depending on which value is reported, some portion of the tensile strength may be used as a design-stress limit. This is valid for gradual static loading at room temperature. For glass-reinforced materials, anisotropic properties render this property useless for design.
Elongation	ASTM D 638	Property reports percent of elongation during the tensile test.	Property is meaningful for elongations from 0 to 15%. Data may be used to set interference limits or strain limits on a design. Strain rate, environmental temperature, and molding flaws such as knit lines must be considered in an actual part. For cases in which elongation exceeds 8%, the material typically has started to yield, and necking occurs. This is well beyond the point useful for design.
Tensile modulus	ASTM D 638	Property reports the stiffness of the material. Value is the slope of the line tangent to the stress-strain curve at the origin.	Tensile modulus may be useful in calculating the deflection. Value is good only for small strains of 1% and at room temperature. Glass-reinforced materials behave anisotropically. Loads applied over extended time need to include creep.
Shear strength	ASTM D 732	Property reports the shear stress calculated by dividing the load required to blank out the specimen by the area, as calculated by the perimeter of the punch times the specimen thickness.	The shear strength may have limited value in design engineering. Stress concentrations and shear rates that vary between the test and an application will affect the accuracy of the value.
[illegible] impact strength	ASTM D 256	Property reports the energy absorbed when a notched specimen is subjected to a shock flexural loading.	Izod impact does not provide usable design information. It can indicate brittle behavior in a material, which would suggest certain approaches to design for impact loads.
Gardner impact	...	Property reports the energy required for a projectile to fracture a sample plaque of the material. The projectile weight, shape, and support configuration are specified.	Gardner impact has very limited design value. The speed, shape, and weight of the projectile are likely to vary from actual use conditions. Also, the manner of support for a molded part differs from that used for the test plaque.
Tensile impact strength...........	ASTM D 1822	Property reports the energy required to fracture a molded specimen subjected to a shock tensile load.	Tensile impact has little design value. It may indicate a brittle material that could affect the design approach employed.
Fracture toughness...............	...	Property reports resistance to crack propagation.	Facilitates material selection
Flexural strength	ASTM D 790	Property reports the maximum fiber stress in a simply supported bar loaded in flexure until either 5% strain is reached or the bar fractures.	Flexural strength has little design value. The value is based on classical elastic equations, which are inaccurate for large deflections, and are based on the assumption that the material obeys Hookes' Law in tension and compression. In actuality, the moduli are different. As with other strength properties, strain rate, temperature, and anisotropic properties limit the usefulness of this property in an application.
Flexural modulus	ASTM D 790	Property reports the stiffness in flexure. Value is obtained by taking the slope of the tangent to the flexural stress-strain curve at origin.	Flexural modulus is useful as an approximation for the elastic modulus in deflection equations, or to convert strain into stress. However, it can be applied only to applications at room temperature and to small deflections. It is widely used in finite element analysis (FEA). Deflection is often the biggest problem in plastic part design.
Compression strength	ASTM D 695	Property reports the maximum compressive stress carried by the test specimen during the compressive test.	Compressive strength cannot be considered significant for design when the application of the loads is widely different from the gradual test application. Fatigue and yielding are not considered and may need to be accounted for in an application.
Poisson's ratio..................	...	...	Poisson's ratio is needed for stress analysis, for both general deflection and FEA.

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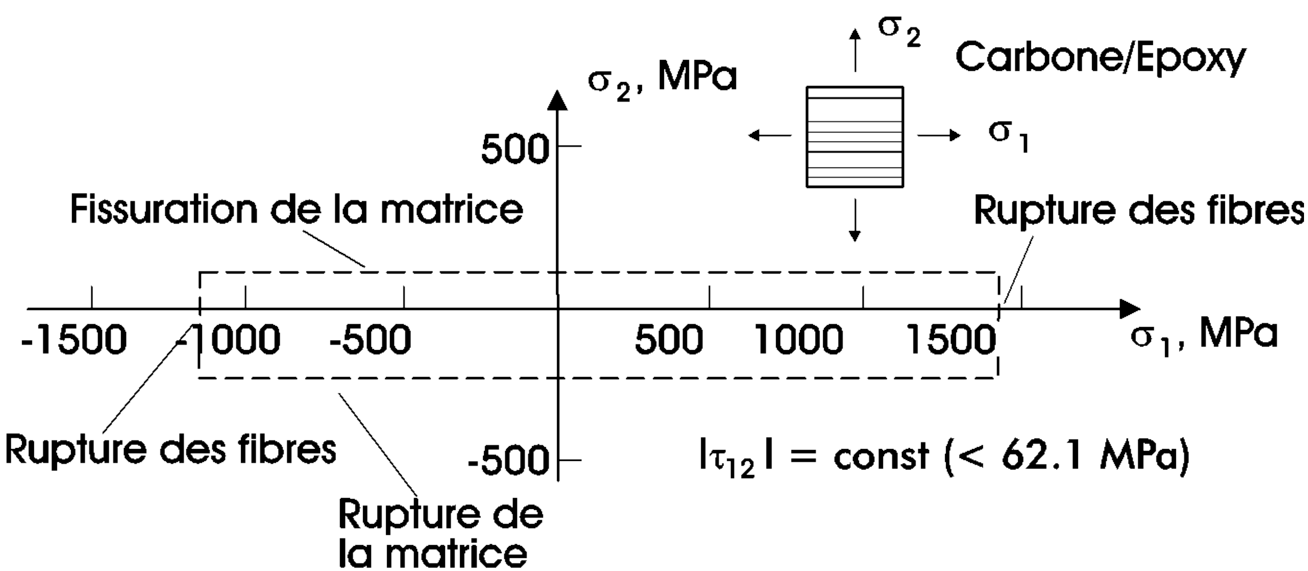
Critères de rupture

- Contraintes maximales
- Déformations maximales
- Critères d'interaction : Hill, Tsai-Hill
- Critère de Tsai-Wu
- Critères de Hashin

Critère de la contrainte maximale

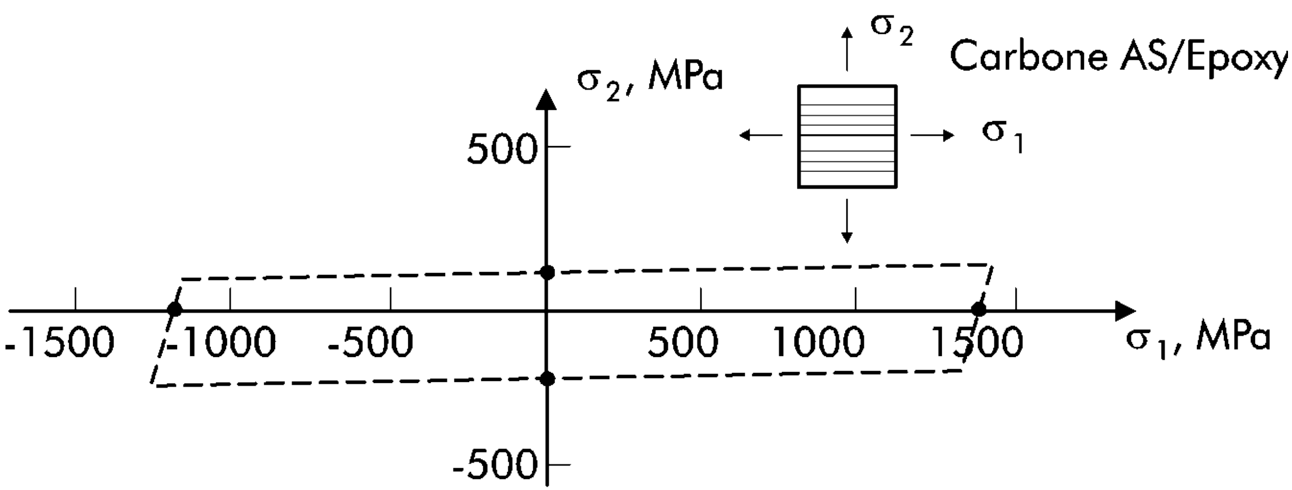
Traction et cisaillement $\sigma_1 = \sigma_{u,1}^T$ $\sigma_2 = \sigma_{u,2}^T$ $|\tau_{12}| = \tau_u$

Compression et cisaillement $|\sigma_1| = \sigma_{u,1}^C$ $|\sigma_2| = \sigma_{u,2}^C$ $|\tau_{12}| = \tau_u$



Critère de la déformation maximale

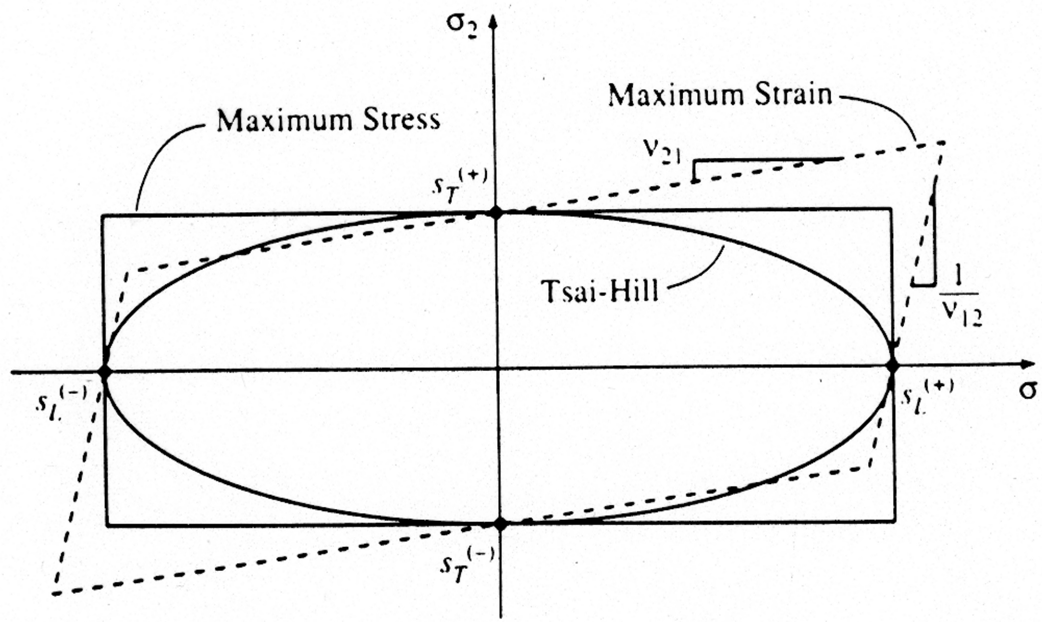
$$-\varepsilon_{u,i}^{C} < \varepsilon_i < \varepsilon_{u,i}^{T}$$



$$\sigma_{u,1} = \frac{\sigma_{u,2}^{T} - \sigma_2}{\nu_{21}} \qquad \sigma_1 > 0$$

Critère de Tsai-Hill

$$\frac{\sigma_1^2 - \sigma_1\sigma_2}{\left(\sigma_{u,1}^T\right)^2} + \frac{\sigma_2^2}{\left(\sigma_{u,2}^T\right)^2} + \frac{\tau_{12}^2}{\tau_u^2} = 1$$



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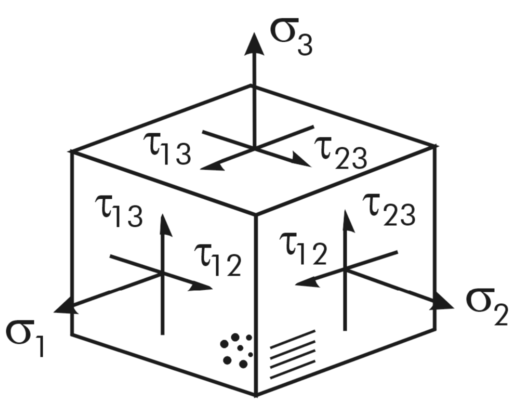
Critère de Tsai-Wu

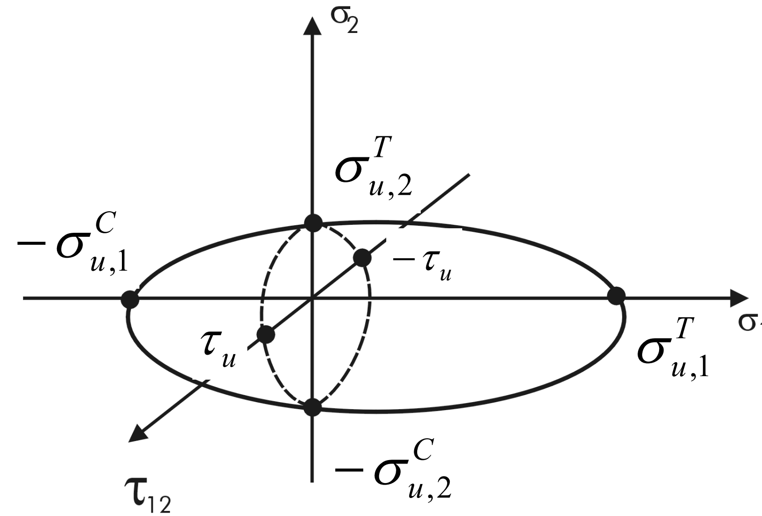
$$F_1\sigma_1 + F_2\sigma_2 + F_{11}\sigma_1^2 + F_{22}\sigma_2^2 + F_{66}\tau_{12}^2 + 2F_{12}\sigma_1\sigma_2 = 1$$

$$F_1 = \frac{1}{\sigma_{u,1}^T} - \frac{1}{\sigma_{u,1}^C} \qquad F_{11} = \frac{1}{\sigma_{u,1}^T\sigma_{u,1}^C}$$

$$F_2 = \frac{1}{\sigma_{u,2}^T} - \frac{1}{\sigma_{u,2}^C} \qquad F_{22} = \frac{1}{\sigma_{u,2}^T\sigma_{u,2}^C}$$

$$F_{66} = \frac{1}{\tau_u^2} \qquad F_{12} = \frac{-\sqrt{F_{11}F_{22}}}{2}$$





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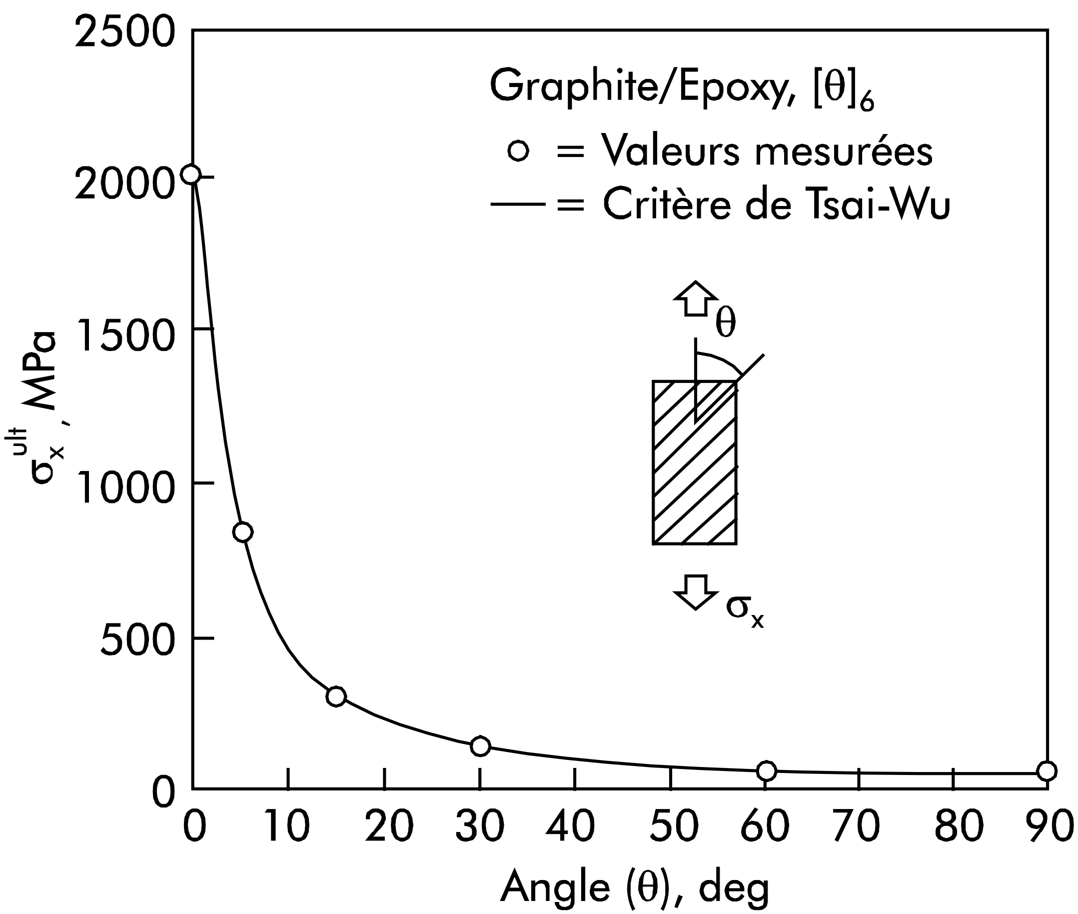
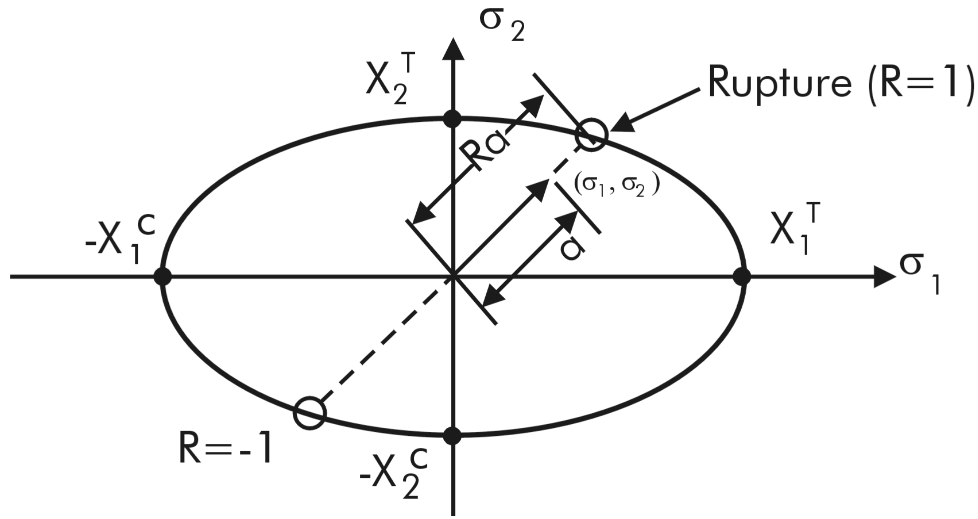
Critère de Tsai-Wu



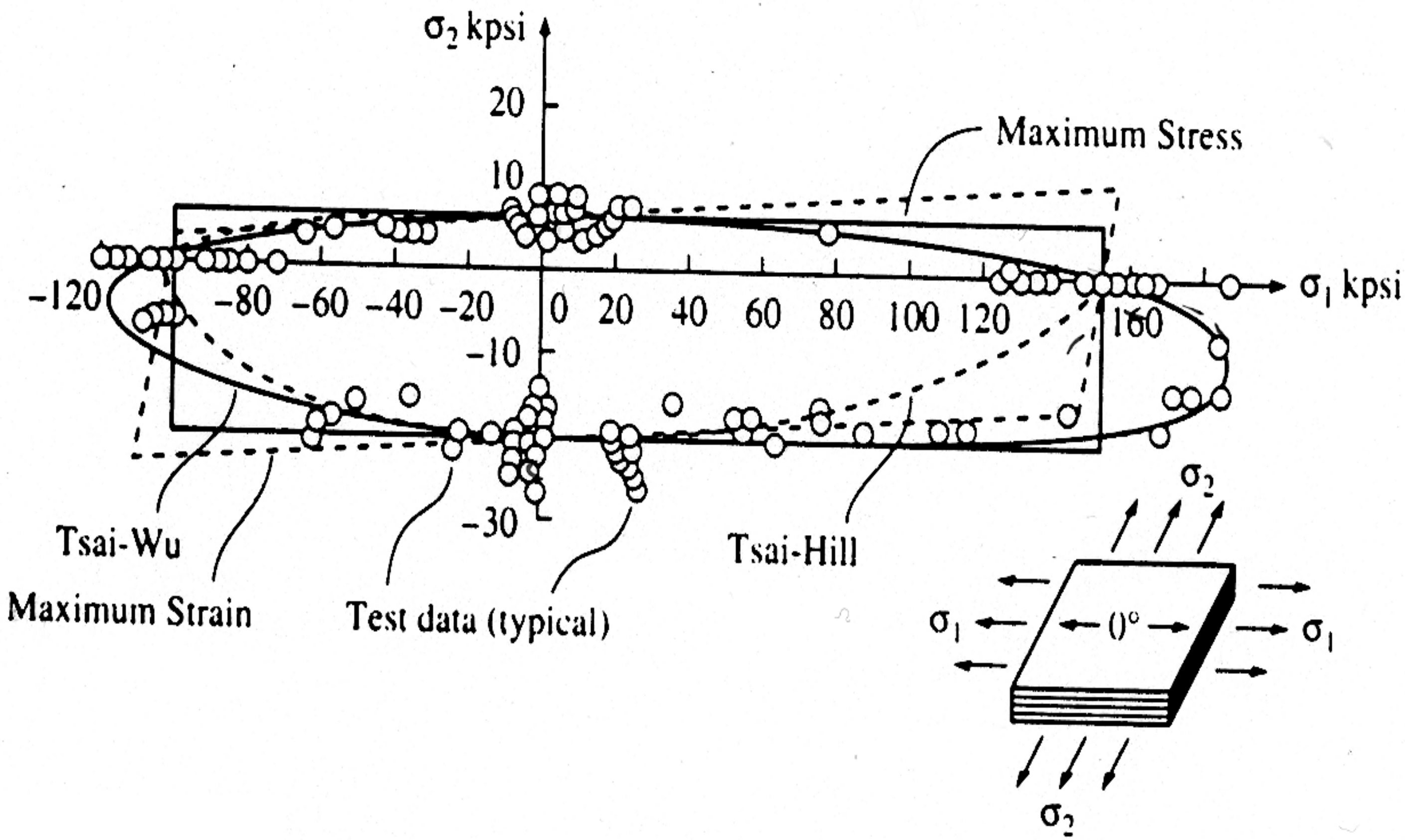
Facteur de sécurité

Reserve Factor



Mathématiquement, la valeur de R est calculée pour n'importe quel état de contraintes appliquées (σ_1, σ_2, τ_{12}) par substitution de ($R\sigma_1$, $R\sigma_2$, $R\tau_{12}$) dans la théorie de la rupture adéquate et en résolvant pour R.

Critères de rupture



Rupture du premier pli puis rupture finale

Contraintes dans les strates

$$[\sigma] = [\overline{Q}]\left(\{\varepsilon^0\} + z\ \{\kappa\}\right)$$

1

2,3...

Nouvel état de contraintes

Critère de rupture

$$\frac{\sigma_1^2 - \sigma_1\sigma_2}{\left(\sigma_{u,1}^T\right)^2} + \frac{\sigma_2^2}{\left(\sigma_{u,2}^T\right)^2} + \frac{\tau_{12}^2}{\tau_u^2} = 1$$

$$\begin{bmatrix} N_x \\ N_y \\ N_{xy} \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} & A_{16} \\ A_{12} & A_{22} & A_{26} \\ A_{16} & A_{26} & A_{66} \end{bmatrix} \begin{bmatrix} \varepsilon_x^0 \\ \varepsilon_y^0 \\ \gamma_{xy}^0 \end{bmatrix} + \begin{bmatrix} B_{11} & B_{12} & B_{16} \\ B_{12} & B_{22} & B_{26} \\ B_{16} & B_{26} & B_{66} \end{bmatrix} \begin{bmatrix} K_x \\ K_y \\ K_{xy} \end{bmatrix}$$

$$\begin{bmatrix} M_x \\ M_y \\ M_{xy} \end{bmatrix} = \begin{bmatrix} B_{11} & B_{12} & B_{16} \\ B_{12} & B_{22} & B_{26} \\ B_{16} & B_{26} & B_{66} \end{bmatrix} \begin{bmatrix} \varepsilon_x^0 \\ \varepsilon_y^0 \\ \gamma_{xy}^0 \end{bmatrix} + \begin{bmatrix} D_{11} & D_{12} & D_{16} \\ D_{12} & D_{22} & D_{26} \\ D_{16} & D_{26} & D_{66} \end{bmatrix} \begin{bmatrix} K_x \\ K_y \\ K_{xy} \end{bmatrix}$$

Rupture d'un pli

$$\left(\overline{Q_{ij}}\right)_{\text{pli rompu}} = 0$$

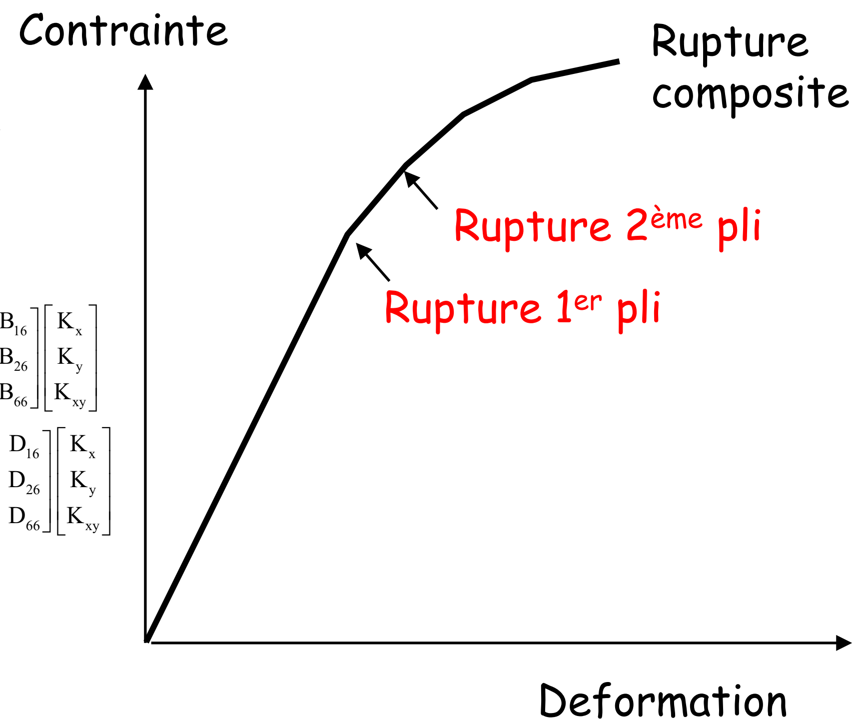
$$A_{ij} = \sum_{k=1}^{N} \left(\overline{Q_{ij}}\right)_k (z_k - z_{k-1})$$

$$B_{ij} = \frac{1}{2}\sum_{k=1}^{N} \left(\overline{Q_{ij}}\right)_k (z_k^2 - z_{k-1}^2)$$

$$D_{ij} = \frac{1}{3}\sum_{k=1}^{N} \left(\overline{Q_{ij}}\right)_k (z_k^3 - z_{k-1}^3)$$

Re-calcul des constantes

First Ply Failure



Dimensionnement : propriétés effectives

Efforts connus
$$\begin{bmatrix} N_x \\ N_y \\ N_{xy} \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} & A_{16} \\ A_{12} & A_{22} & A_{26} \\ A_{16} & A_{26} & A_{66} \end{bmatrix} \begin{bmatrix} \varepsilon_x^0 \\ \varepsilon_y^0 \\ \gamma_{xy}^0 \end{bmatrix}$$

h = épaisseur du stratifié

Contraintes globales moyennes (fictives)

$$\begin{bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{bmatrix} = 1/\mathrm{h} \begin{bmatrix} N_x \\ N_y \\ N_{xy} \end{bmatrix} = 1/\mathrm{h} \begin{bmatrix} A_{11} & A_{12} & A_{16} \\ A_{12} & A_{22} & A_{26} \\ A_{16} & A_{26} & A_{66} \end{bmatrix} \begin{bmatrix} \varepsilon_x^0 \\ \varepsilon_y^0 \\ \gamma_{xy}^0 \end{bmatrix}$$

$$\frac{1}{\mathrm{h}} \mathrm{A}_{\mathrm{ij}} = \sum_{\mathrm{k}=1}^{\mathrm{N}} \left(\overline{\mathrm{Q}_{\mathrm{ij}}}\right)_{\mathrm{k}} \frac{\text{épaisseur}_{\mathrm{k}}}{\mathrm{h}} = \sum_{\mathrm{k}=1}^{\mathrm{N}} \left(\overline{\mathrm{Q}_{\mathrm{ij}}}\right)_{\mathrm{k}} \text{pourcentage}_{\mathrm{k}}$$

$$\begin{bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{bmatrix} = \mathrm{h}. \begin{bmatrix} A_{11} & A_{12} & A_{16} \\ A_{12} & A_{22} & A_{26} \\ A_{16} & A_{26} & A_{66} \end{bmatrix}^{-1} \begin{bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{bmatrix} = \begin{bmatrix} \frac{1}{E_x} & -\frac{\nu_{xy}}{E_x} & 0 \\ -\frac{\nu_{yx}}{E_y} & \frac{1}{E_y} & 0 \\ 0 & 0 & \frac{1}{G_{xy}} \end{bmatrix} \begin{bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{bmatrix}$$

Modules effectifs

Dimensionnement : déformation et épaisseur minimale

Choisir des pourcentages initiaux

Calculer $\frac{1}{h}A_{ij} = \sum_{k=1}^{N} \left(\overline{Q_{ij}}\right)_k \text{pourcentage}_k$

Inverser pour obtenir modules effectifs E_x, E_y …. et les déformations

Critère de rupture pour le pli k en entrant dans le critère
de rupture $h\,\sigma_x$ qui est connu car = N_x

$$\frac{\left(h\sigma_1\right)^2 - h\sigma_1 h\sigma_2}{\left(\sigma_{u,1}^T\right)^2} + \frac{\left(h\sigma_2\right)^2}{\left(\sigma_{u,2}^T\right)^2} + \frac{\left(h\tau_{12}\right)^2}{\tau_u^2} = h_k^{\ 2}$$

h pour éviter la rupture du pli k est donc connu

idem pour autres plis

Choisir le h = sup(h_k)

Pourcentages initiaux technologiques

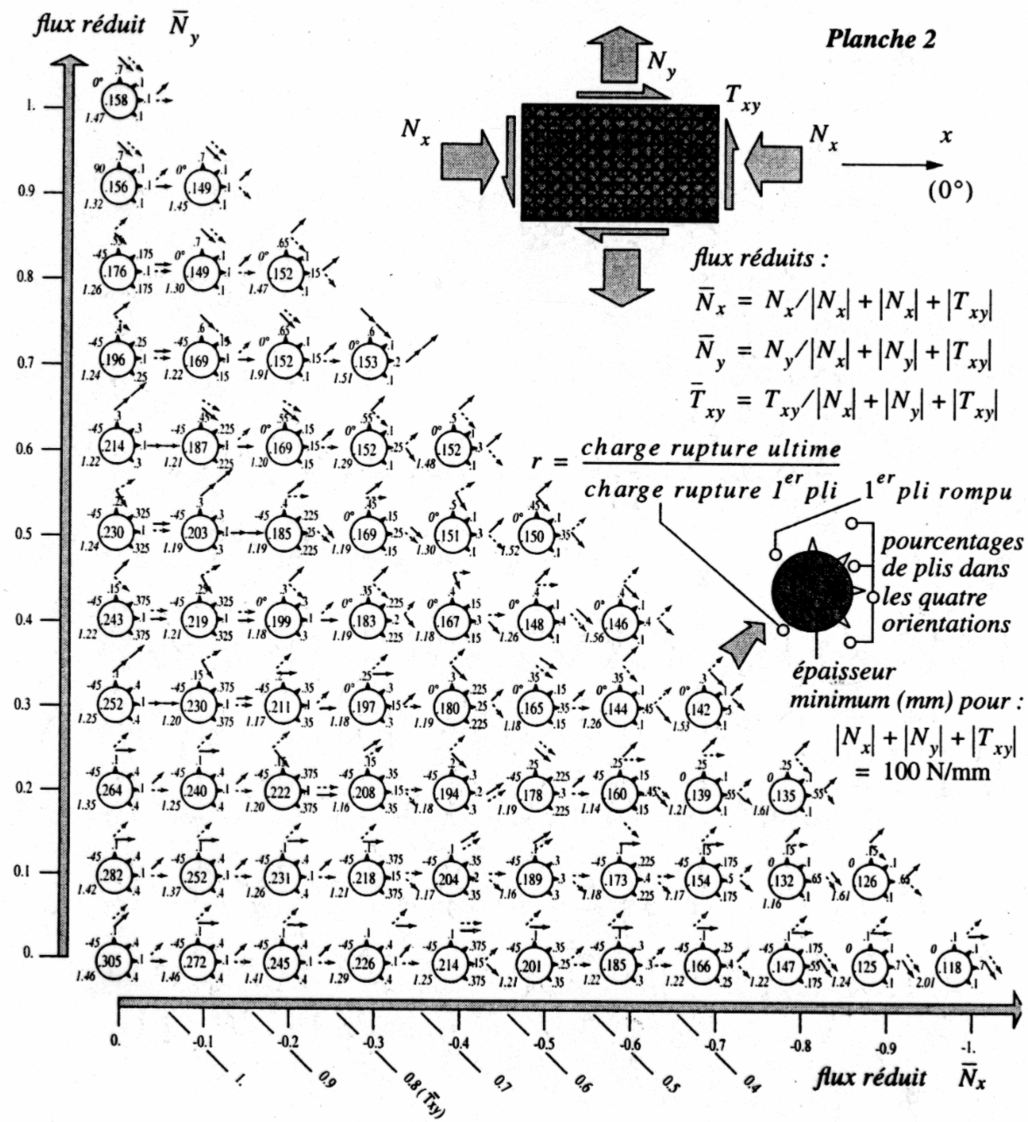
- Proportion minimum de 5 à 10% dans chaque direction 0, 90, +45, -45
- Epaisseur minimale du stratifié de l'ordre du mm (8 couches UD ou 3 à 4 couches de tissu équilibré)
- Considérer les directions des efforts principaux
- Plis à 90 placés en surface, puis plis à 45, puis à 0 lorsque les efforts prépondérants sont à 0
- Pas plus de 4 plis consécutif dans une même direction

Guides de conception

Composition optimum d'un stratifié carbone/époxyde

V_f = 0,6 ; caractéristiques du pli : *cf.* annexe 1 ou paragraphe 3.3.3.

10 % minimum de plis dans chaque direction 0°, 90°, + 45°, – 45°



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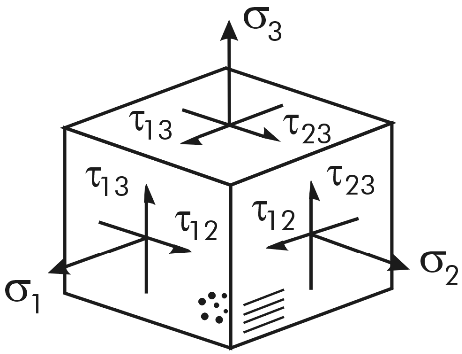
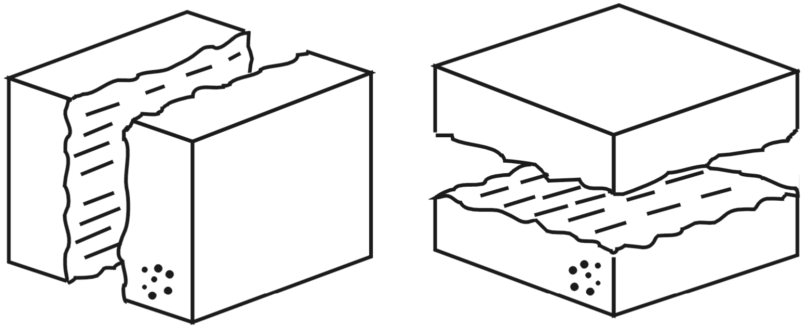
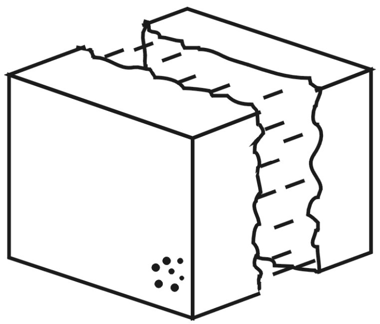
Endommagement

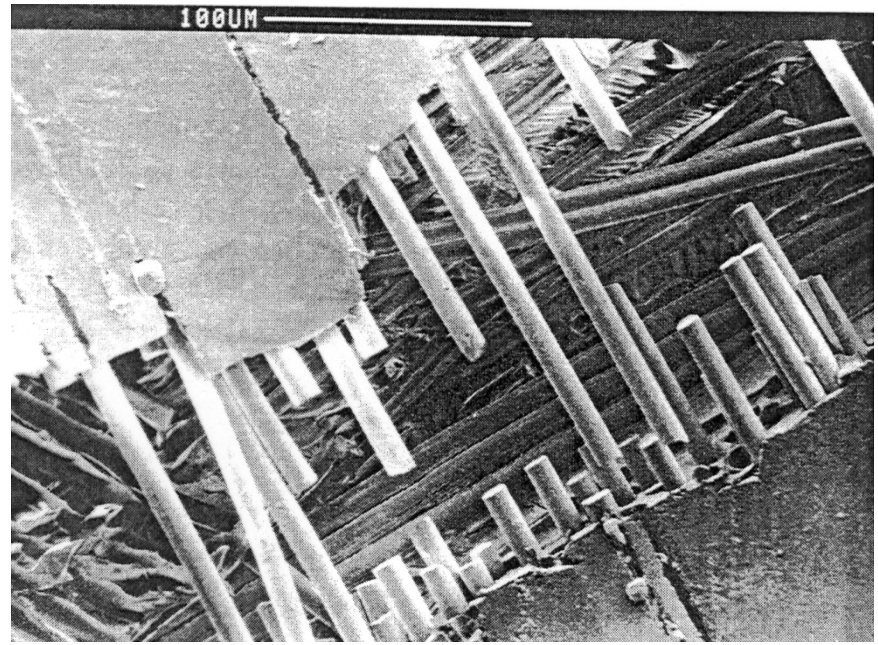




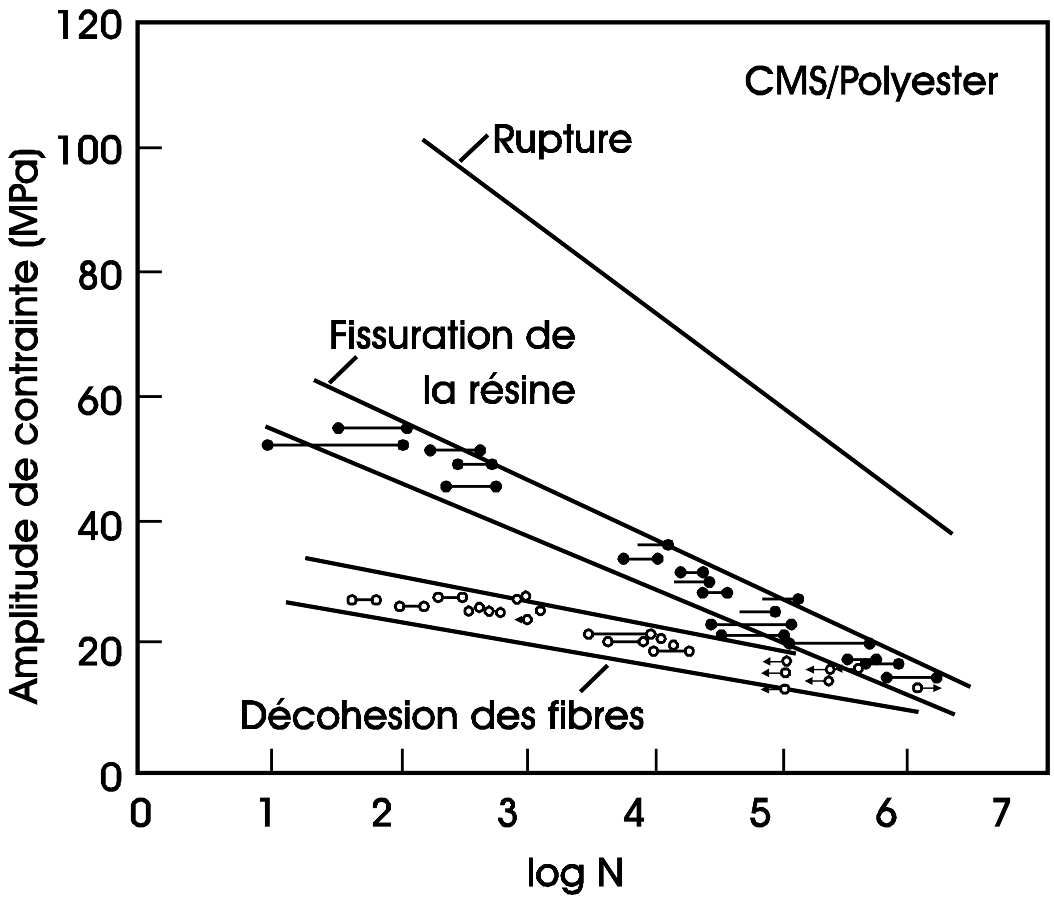
(b) Rupture de la matrice



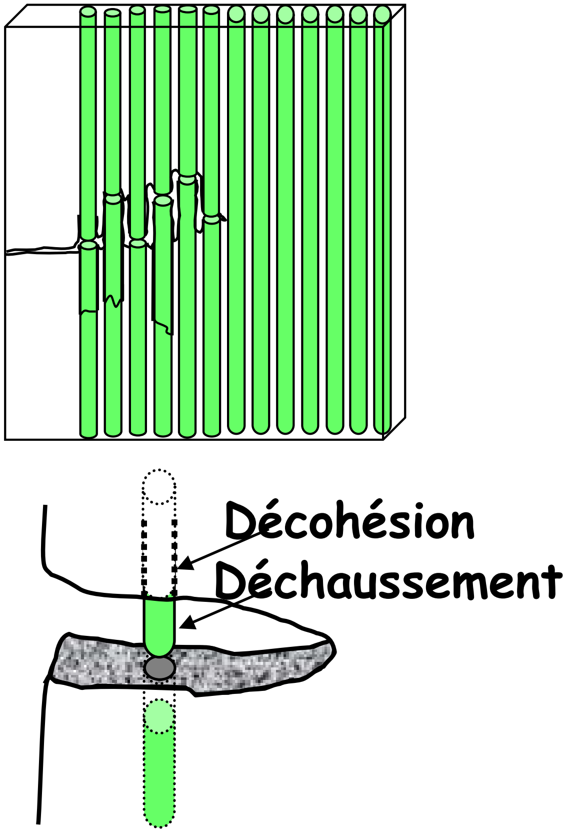
(c) Arrachage/rupture des fibres

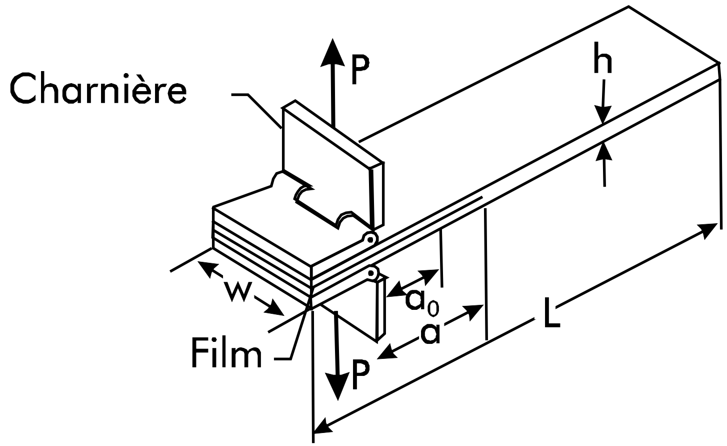


Fatigue des composites



Propagation de fissures





Approche G_{IC}, courbes R

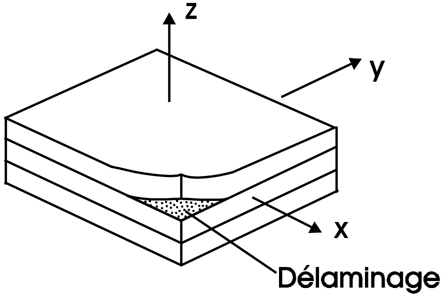
https://tube.switch.ch/videos/9333a14a

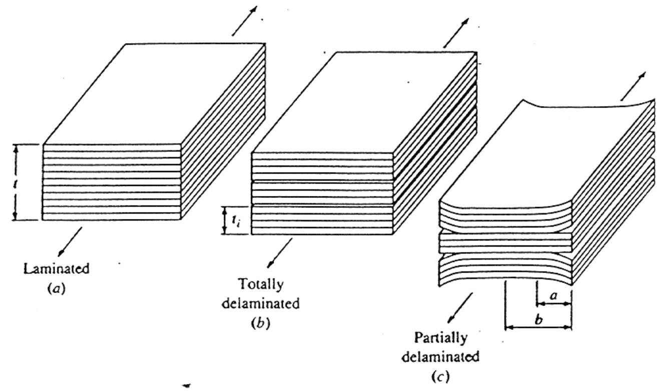
Energie de rupture typique d 'une matrice thermodurcie: ~100 J/m^2

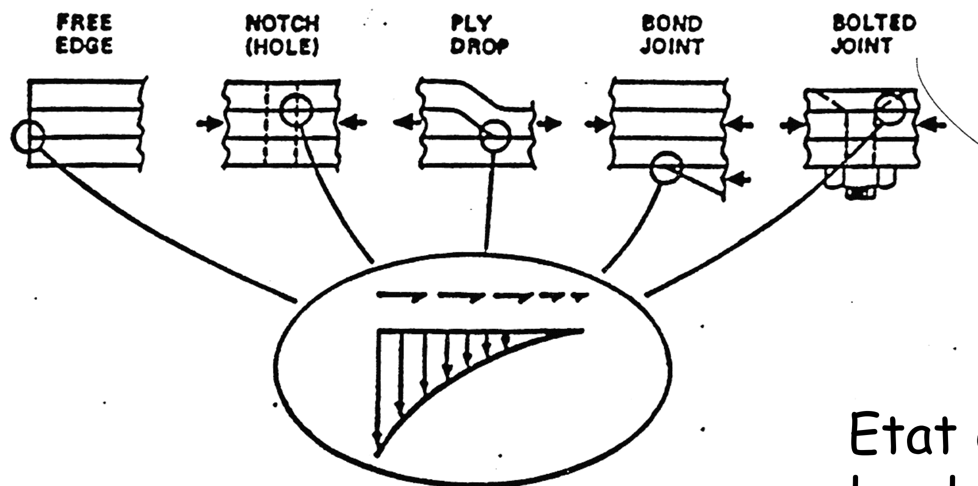
des fibres de verre: ~10 J/m^2

d 'un composite: ~ 10000 J/m^2

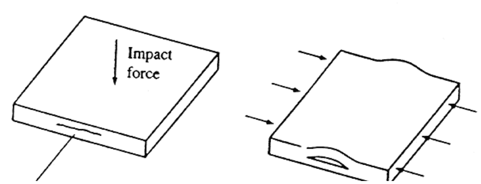
Le délaminage







Etat de contraintes locales complexe



Mécanique des composites

Micro et macromécanique

Tests mécaniques

Endommagement et rupture

CADFEM

Applications

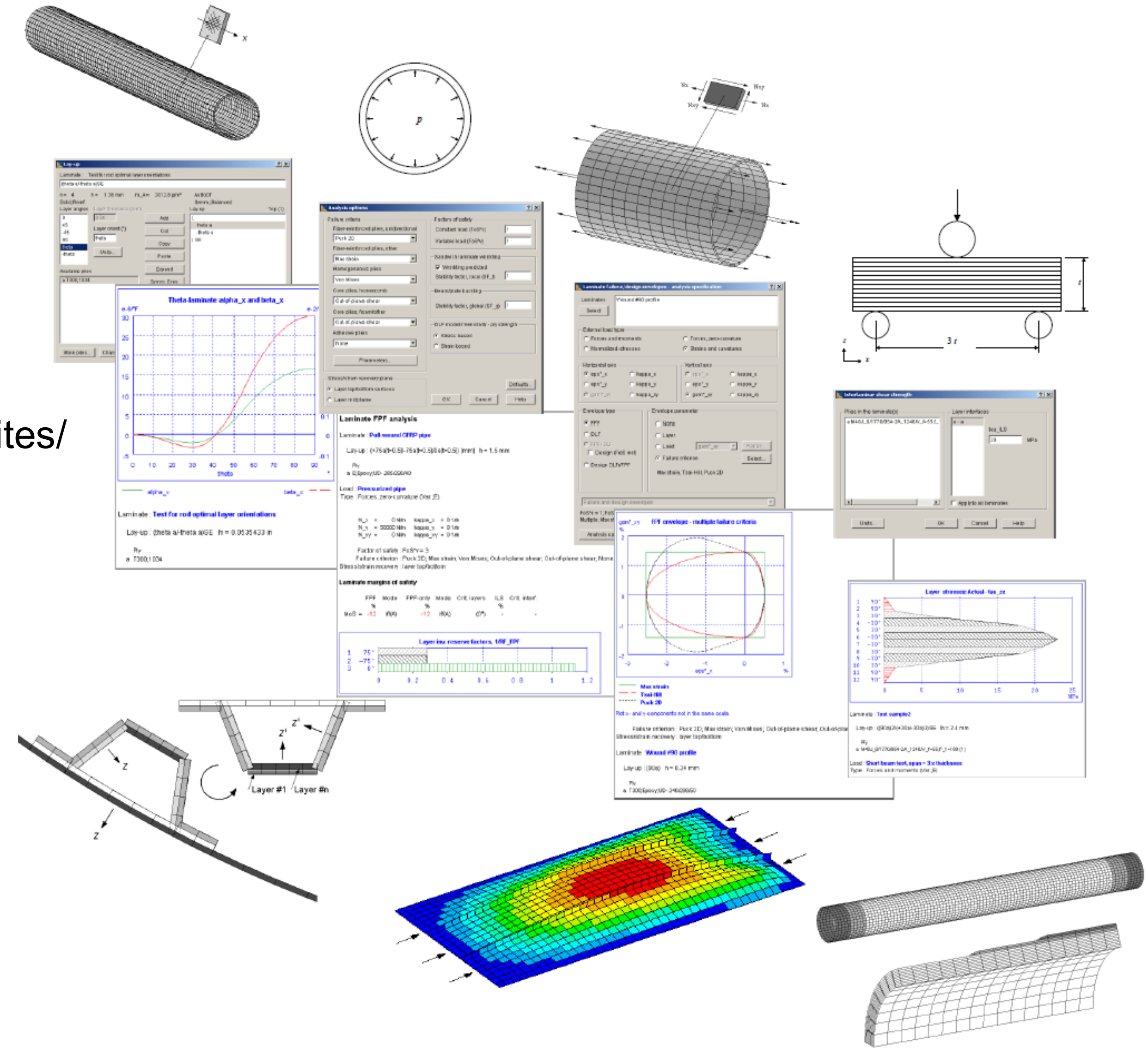
Les stratifiés

Structures sandwich

Composites textiles

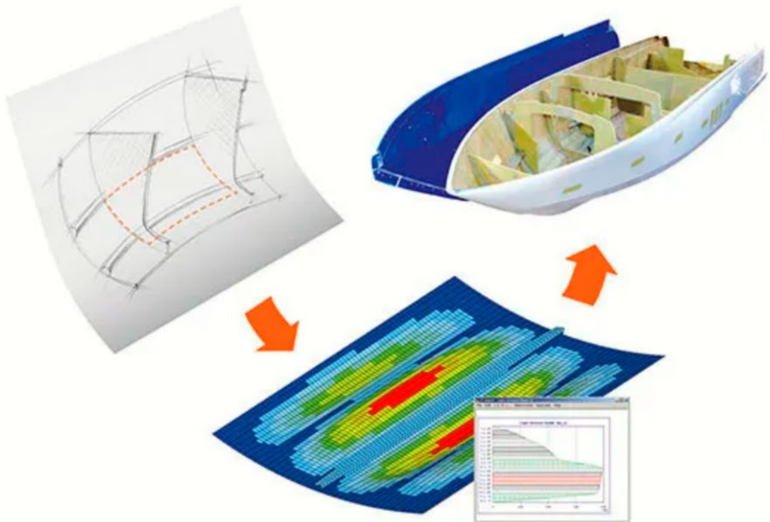
Mécanique des composites stratifiés

https://www.altair.com/composites/

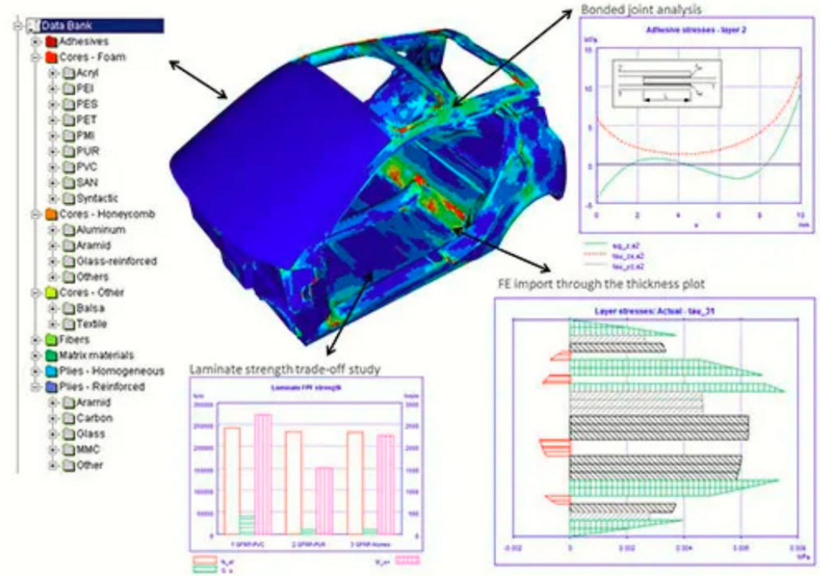


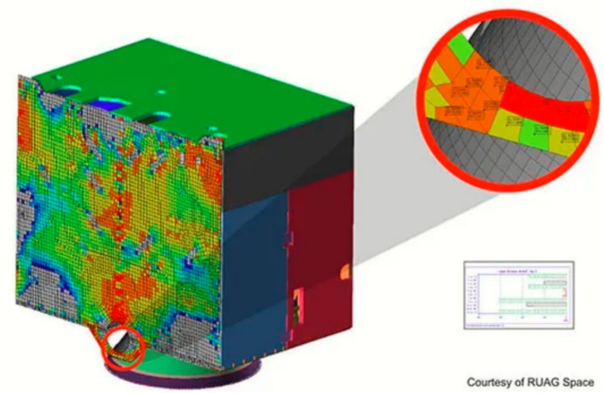
pierre-etienne.bourban@epfl.ch

FEM

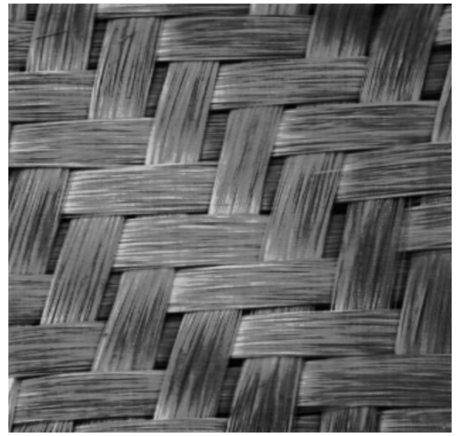


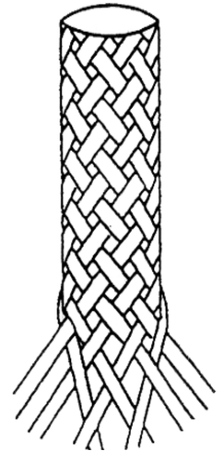
https://filecr.com/windows/esacomp/?id=13436849765

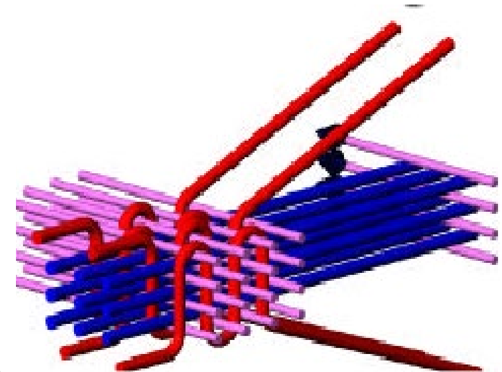


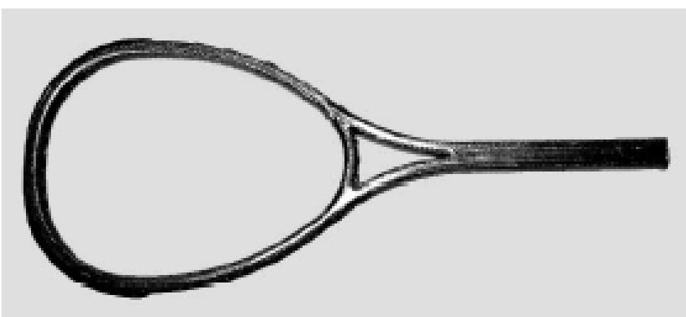


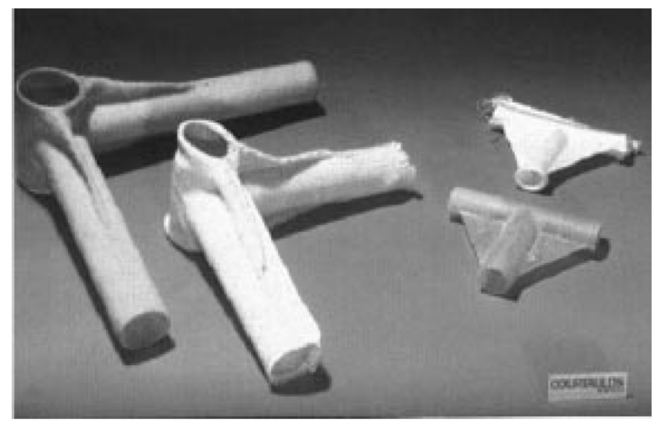
Les composites textiles



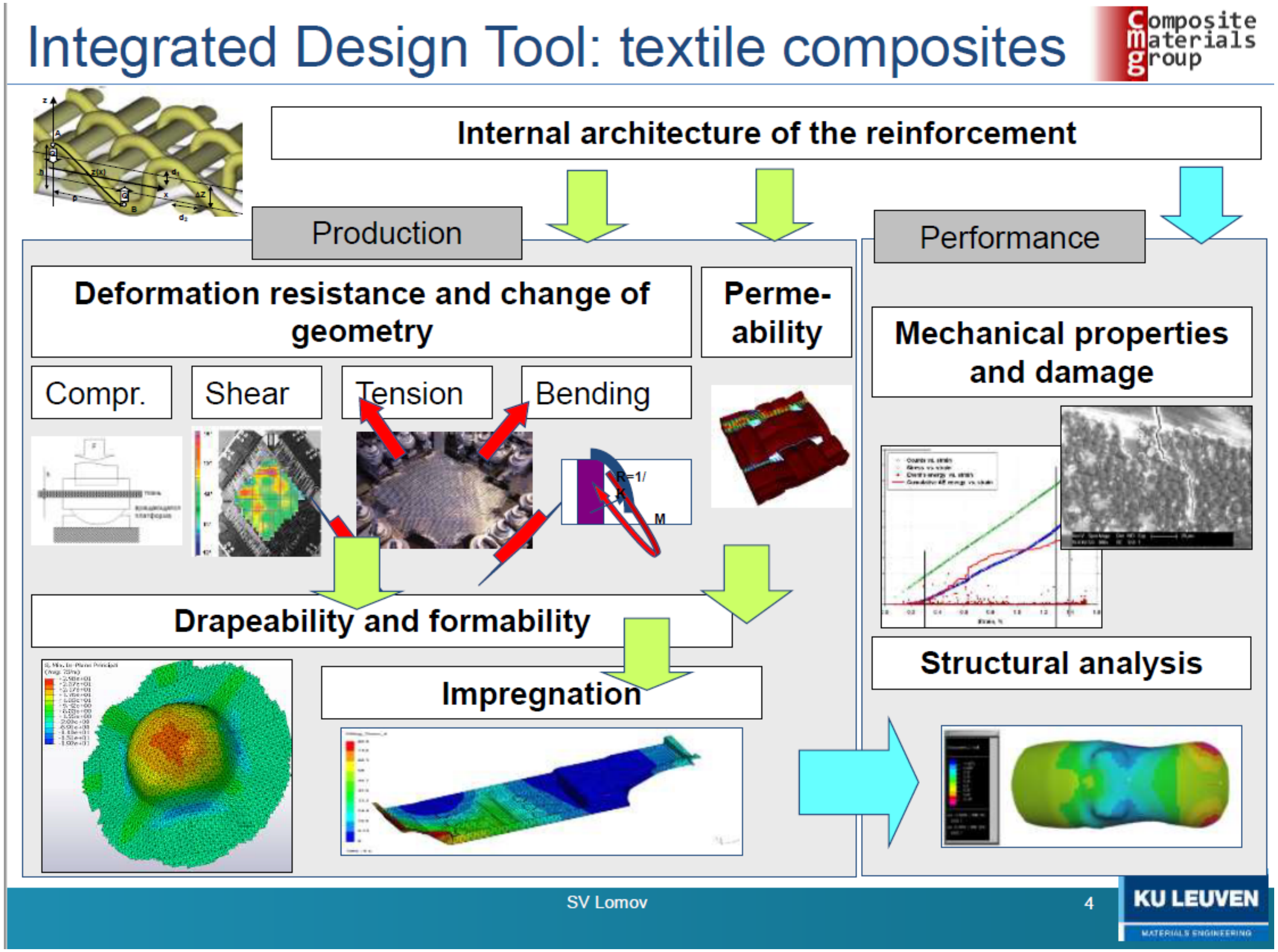






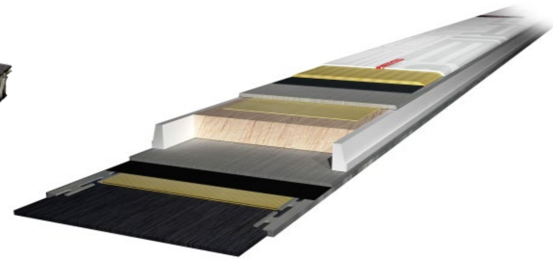


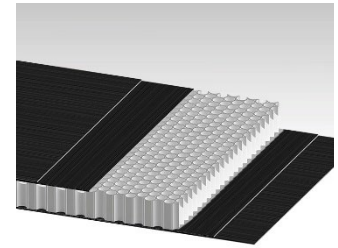
Les composites textiles

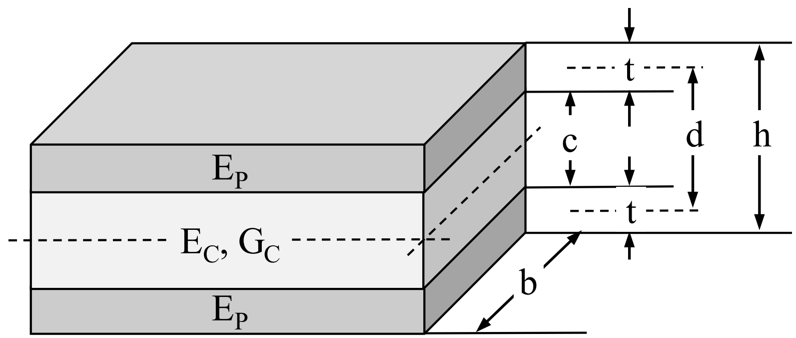


https://www.mtm.kuleuven.be/onderzoek/scalint/Composites/software/wisetex

Structures sandwich



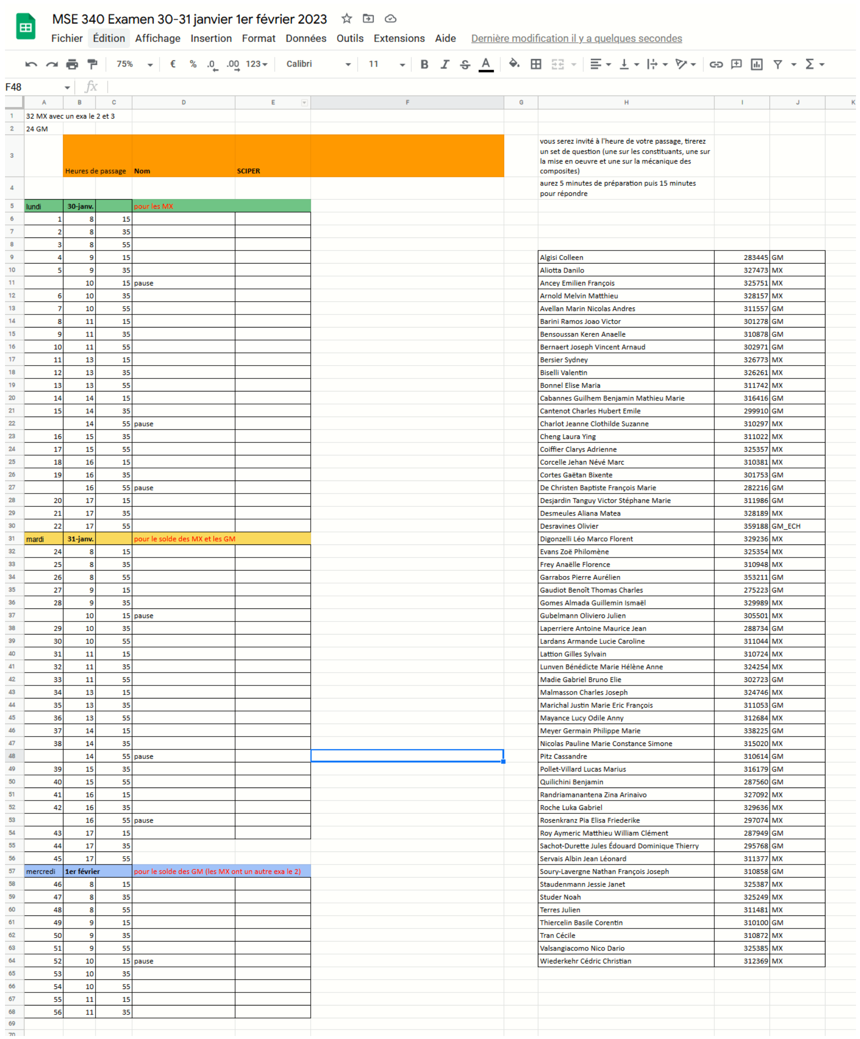




$$D \approx D' = E_P \frac{b\,t\,d^2}{2}$$

Révision et examen

https://docs.google.com/spreadsheets/d/1vMpbdes4FlINZgwfZNScfrZTd3DPYVLIwxQKzwLknu0/edit#gid=0


MSE 340 Examen 30-31 janvier 1er février 2023

Fichier Édition Affichage Insertion Format Données Outils Extensions Aide Dernière modification il y a quelques secondes

F48

	A	B	C	D	E	F	G	H	I	J
1	32 MX avec un exa le 2 et 3									
2	24 GM									
3		Heures de passage		Nom	SCIPER			vous serez invité à l'heure de votre passage, tirerez un set de question (une sur les constituants, une sur la mise en oeuvre et une sur la mécanique des composites)		
4								aurez 5 minutes de préparation puis 15 minutes pour répondre		
5	lundi	30-janv.		pour les MX						
6	1	8	15							
7	2	8	35							
8	3	8	55							
9	4	9	15					Algisi Colleen	283445	GM
10	5	9	35					Aliotta Danilo	327473	MX
11		10	15	pause				Ancey Emilien François	325751	MX
12	6	10	35					Arnold Melvin Matthieu	328157	MX
13	7	10	55					Avellan Marin Nicolas Andres	311557	GM
14	8	11	15					Barini Ramos Joao Victor	301278	GM
15	9	11	35					Bensoussan Keren Anaelle	310878	GM
16	10	11	55					Bernaert Joseph Vincent Arnaud	302971	GM
17	11	13	15					Bersier Sydney	326773	MX
18	12	13	35					Biselli Valentin	326261	MX
19	13	13	55					Bonnel Elise Maria	311742	MX
20	14	14	15					Cabannes Guilhem Benjamin Mathieu Marie	316416	GM
21	15	14	35					Cantenot Charles Hubert Emile	299910	GM
22		14	55	pause				Charlot Jeanne Clothilde Suzanne	310297	MX
23	16	15	35					Cheng Laura Ying	311022	MX
24	17	15	55					Coiffier Clarys Adrienne	325357	MX
25	18	16	15					Corcelle Jehan Névé Marc	310381	MX
26	19	16	35					Cortes Gaëtan Bixente	301753	GM
27		16	55	pause				De Christen Baptiste François Marie	282216	GM
28	20	17	15					Desjardin Tanguy Victor Stéphane Marie	311986	GM
29	21	17	35					Desmeules Aliana Matea	328189	MX
30	22	17	55					Desravines Olivier	359188	GM_ECH
31	mardi	31-janv.		pour le solde des MX et les GM				Digonzelli Léo Marco Florent	329236	MX
32	24	8	15					Evans Zoë Philomène	325354	MX
33	25	8	35					Frey Anaëlle Florence	310948	MX
34	26	8	55					Garrabos Pierre Aurélien	353211	GM
35	27	9	15					Gaudiot Benoît Thomas Charles	275223	GM
36	28	9	35					Gomes Almada Guillemin Ismaël	329989	MX
37		10	15	pause				Gubelmann Oliviero Julien	305501	MX
38	29	10	35					Laperriere Antoine Maurice Jean	288734	GM
39	30	10	55					Lardans Armande Lucie Caroline	311044	MX
40	31	11	15					Lattion Gilles Sylvain	310724	MX
41	32	11	35					Lunven Bénédicte Marie Hélène Anne	324254	MX
42	33	11	55					Madie Gabriel Bruno Elie	302723	GM
43	34	13	15					Malmasson Charles Joseph	324746	MX
44	35	13	35					Marichal Justin Marie Eric François	311053	GM
45	36	13	55					Mayance Lucy Odile Anny	312684	MX
46	37	14	15					Meyer Germain Philippe Marie	338225	GM
47	38	14	35					Nicolas Pauline Marie Constance Simone	315020	MX
48		14	55	pause				Pitz Cassandre	310614	GM
49	39	15	35					Pollet-Villard Lucas Marius	316179	GM
50	40	15	55					Quilichini Benjamin	287560	GM
51	41	16	15					Randriamanantena Zina Arinaivo	327092	MX
52	42	16	35					Roche Luka Gabriel	329636	MX
53		16	55	pause				Rosenkranz Pia Elisa Friederike	297074	MX
54	43	17	15					Roy Aymeric Matthieu William Clément	287949	GM
55	44	17	35					Sachot-Durette Jules Édouard Dominique Thierry	295768	GM
56	45	17	55					Servais Albin Jean Léonard	311377	MX
57	mercredi	1er février		pour le solde des GM (les MX ont un autre exa le 2)				Soury-Lavergne Nathan François Joseph	310858	GM
58	46	8	15					Staudenmann Jessie Janet	325387	MX
59	47	8	35					Studer Noah	325249	MX
60	48	8	55					Terres Julien	311481	MX
61	49	9	15					Thiercelin Basile Corentin	310100	GM
62	50	9	35					Tran Cécile	310872	MX
63	51	9	55					Valsangiacomo Nico Dario	325385	MX
64	52	10	15	pause				Wiederkehr Cédric Christian	312369	MX
65	53	10	35							
66	54	10	55							
67	55	11	15							
68	56	11	35							

	A	B	C	D	E
1	Questions pour la séance de révision du 19 décembre				
2					
3	Questions sur la mise en oeuvre des composites				
4					
5	XXXXXX				
6					
7					
8					
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10					
11					
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14					
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18					
19	Questions sur la mécanique des composites				
20					
21	yyyyy				
22					
23					
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30					
31					