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Evaluation Of Interference Genotypes – Energy Release Rate By Using Wedge Splitting Test

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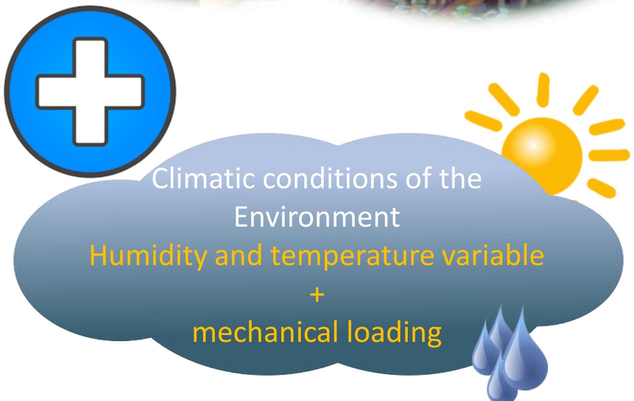
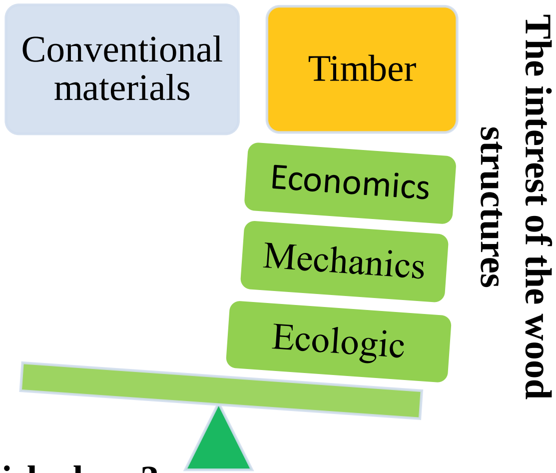
CONTEXT: DURABILITY WOODEN STRUCTURES



- Low consumption of energy
- Ability to store Carbone dioxide

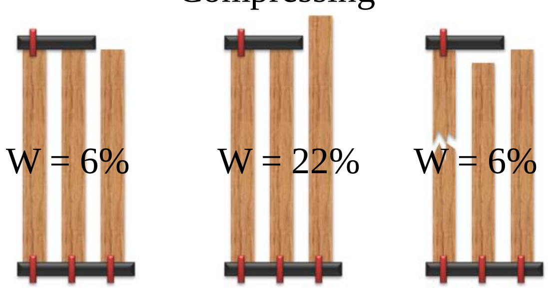
Environmental challenges



Risk class 3

Service conditions	Sensitive zone	Biological risk
Timber frequently subjected to moisture content > 20% without stagnation of water	All the wettable zone naturally not durable	-fungus -cleopteres -Termites

Compressing



Shrinkage and swelling

CONTEXT: DURABILITY WOODEN STRUCTURES

The Douglas has remarkable resistance to fungal agents and dimensional stability.

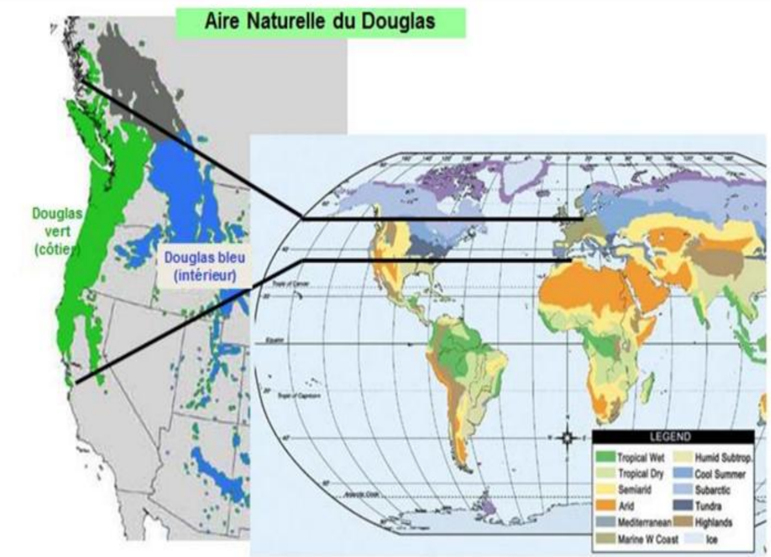
It is native from the West Coast of the North American continent.

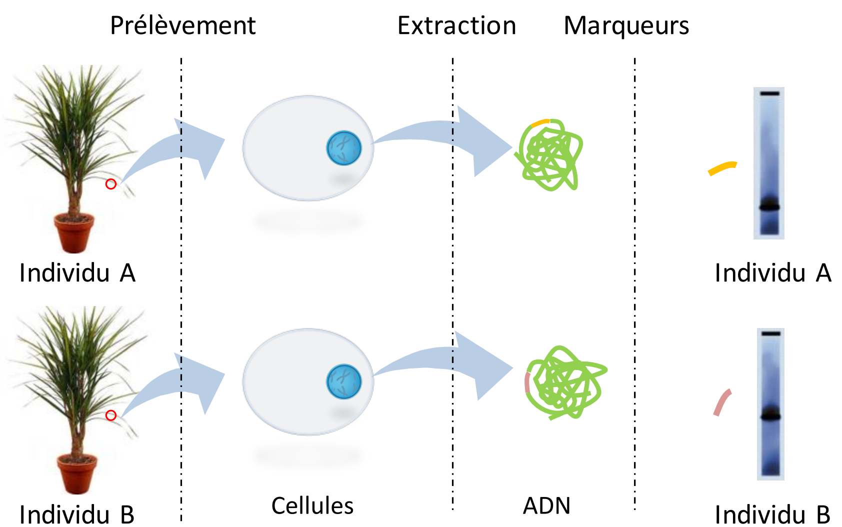
It introduced in France at the beginning of the 19th century and Today it is the main emerging forest resource of the national territory.

The silviculturists have soon realized that there are some provenances more interesting than others in terms of adaptability.

Forest selection programs begin with an assessment of seeds from the natural range and tested in different sites. The provenance / progeny tests have contributed to the selection of some Clones considered to be interesting in terms of adaptability.

This material allowed the planting of different French seed orchards in many sites in France.



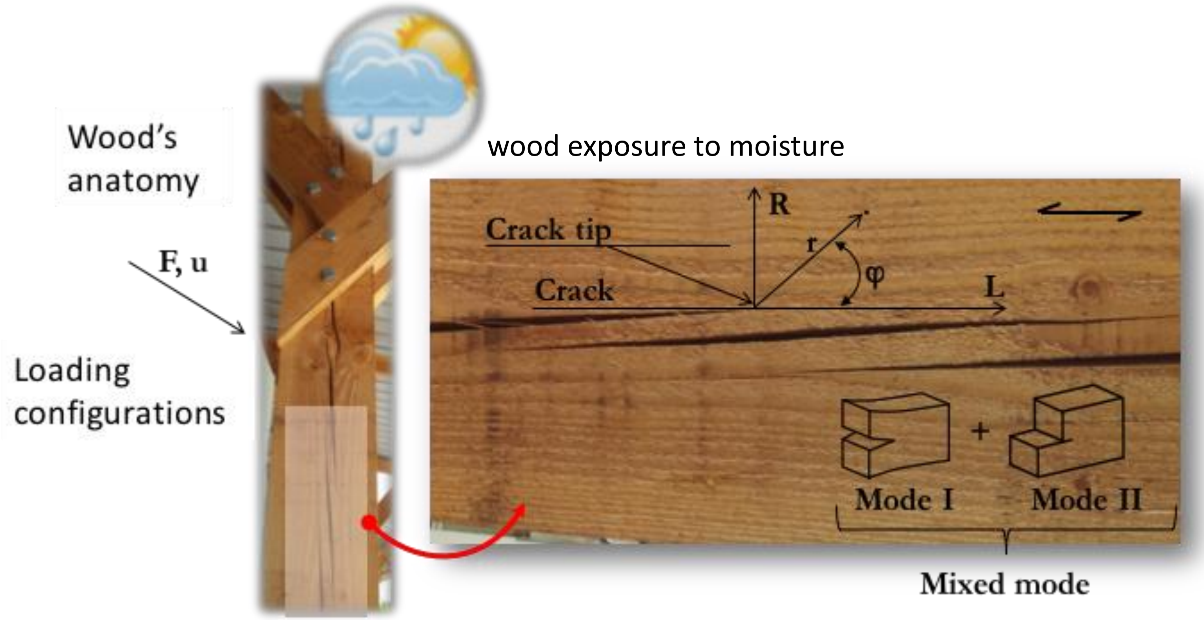


Douglas which is the subject of this study, comes from one of these plantations located in Gimel the cascades in Corrèze (France), It results from a propagation by cuttings of some of these clones.

CONTEXT: DURABILITY WOODEN STRUCTURES

- Depending on the surrounding conditions, wood tends to absorb or desorb moisture.
- The interaction between the moisture and the cell walls results in dimensional variations.
- Due to its nature, wood possesses a micro cracks network.
- The networks of cracks can develop and lead to the partial or total structure collapse.

The fracture parameters inform the mechanical state of the material



the fracture process can be dissociated into three pure modes :

- mode I : is an opening mode.
- mode II : is associated to a shear loading.
- Mode III : is a tearing.

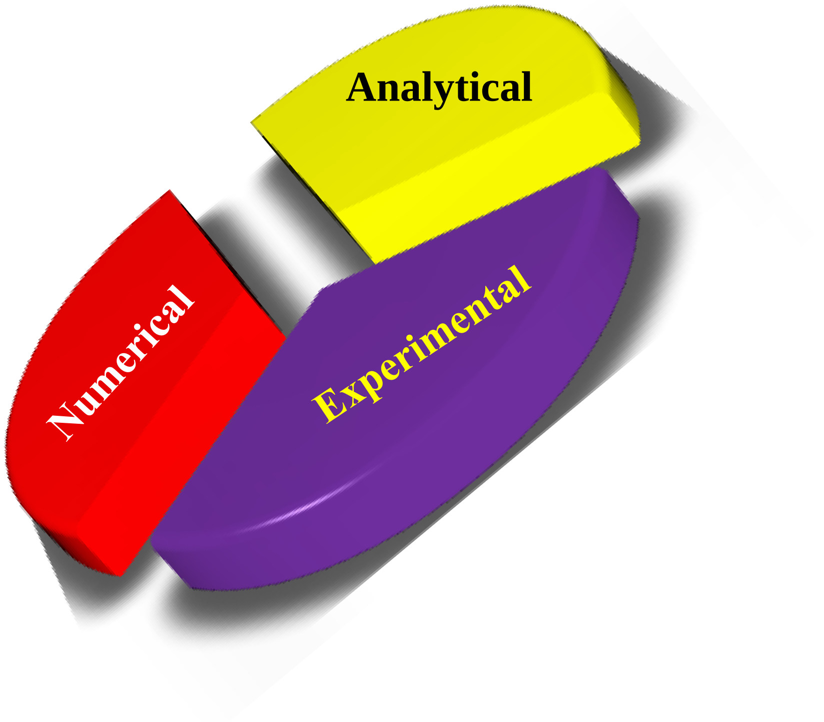
SUMMARY

I Introduction in fracture mechanics

O Optical methods

P Preliminary results

C&P Conclusions and Perspectives



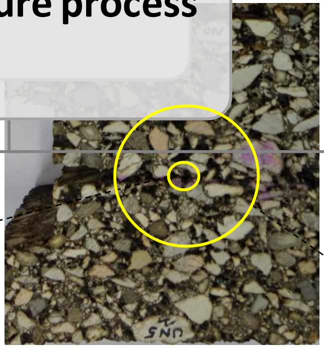
INTRODUCTION

Fracture mechanics

Opening mode

The cracking is a real problem which affects timber structures durability

Fracture process



Local Approach

Global Approach

- Local behavior.
- Local mechanical fields (near to the crack tip).
- Crack tip singularity.
- Observation of the process zone

- Energetic approaches.
- Integral invariants J, G and M.
- Mechanical fields far to crack tip.

It’s important to evaluate the failure risk and the mechanical state in order to verify if the crack is stationary or if the failure risk is imminent.

INTRODUCTION

Fracture mechanics

Global Approach

Energy release rate

Integration domain

The global approach is based on energetic methods
The evaluation of the energy release rate can be realized using invariant INTEGRALS :

$$J = \int_{\Gamma} \left(W \cdot n_1 - T_i \cdot \frac{\partial u_i}{\partial x_1} \right) \cdot ds$$

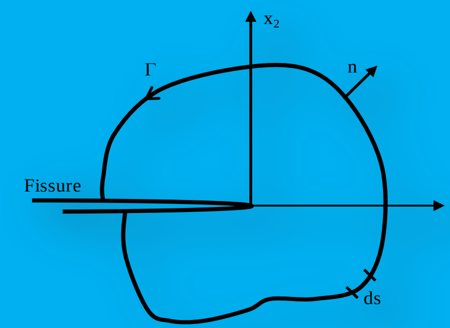
Constitutive law.
To calculate the complementary mechanical fields.

Measurement of the displacement field

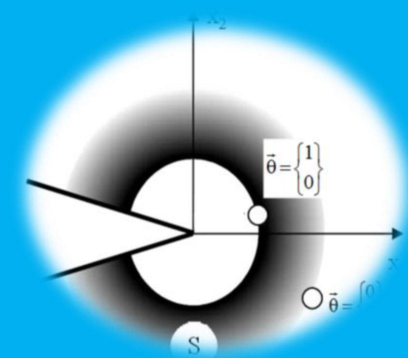
$$G\theta = \int_{S} \left(-W \cdot \theta_{k,k} + \sigma_{ij} \cdot u_{i,k} \cdot \theta_{k,j} \right) \cdot dS$$

The knowledge of the material constitutive law is necessary

curvilinear integration

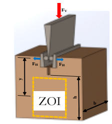


surface integration



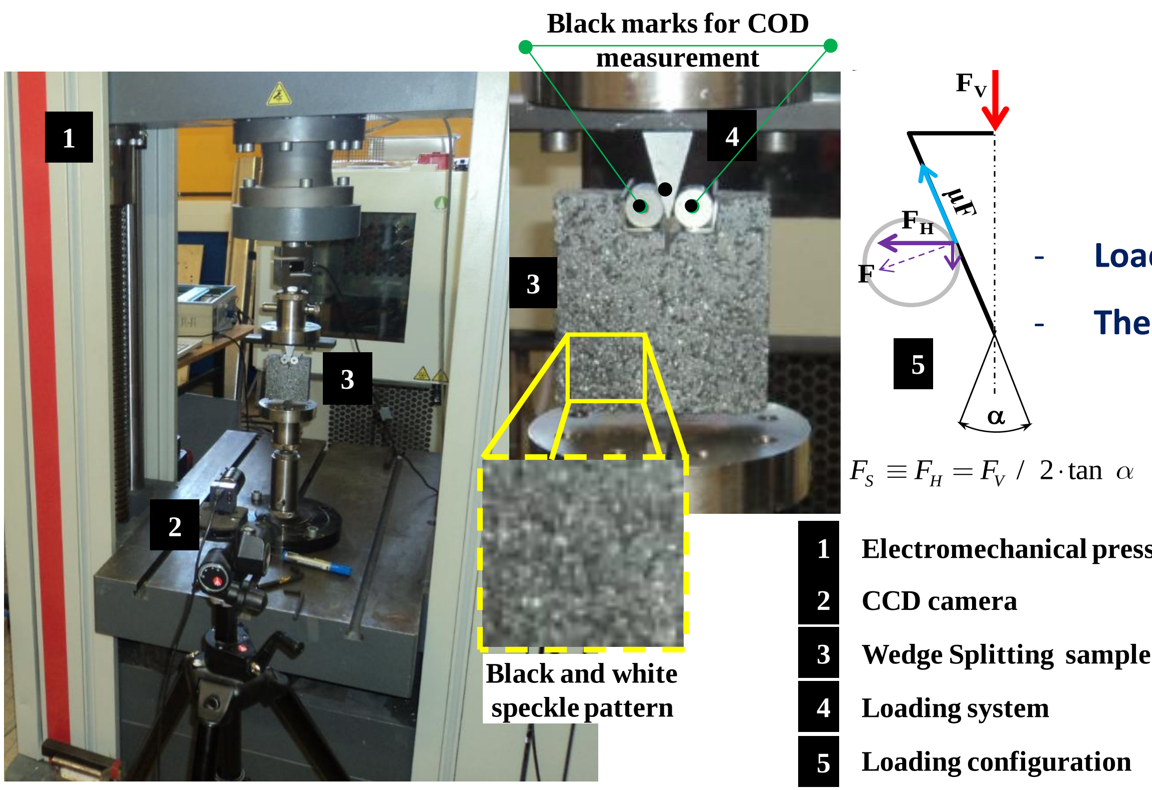
RESULTS

Material and methods



Wedge Splitting Test

The fracture parameters in opening mode were identified from a wedge splitting test (opening mode).

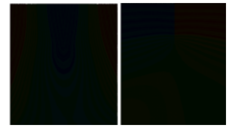


- Loading under controled displacement.
- The samples moisture content is estimated at 9%.

The loading configuration

OPTICAL METHODS

DIC & MTm



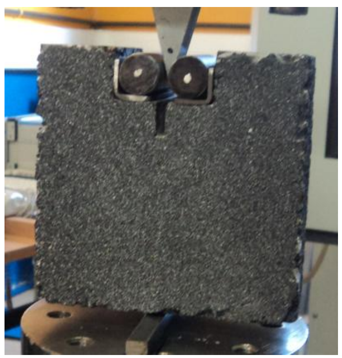
Measurement of displacement field

Digital image correlation

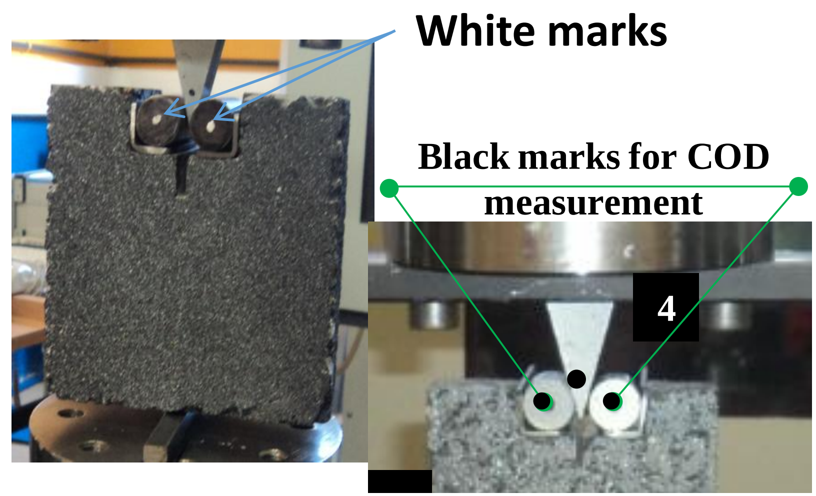
Mark Tracking method

- **The displacement is calculated by comparing the initial image (F=0) with the image corresponding to the loading state.**

Sample with black and white speckle pattern



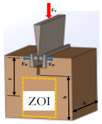
To measure the displacement fields



To observe the loading boundaries conditions

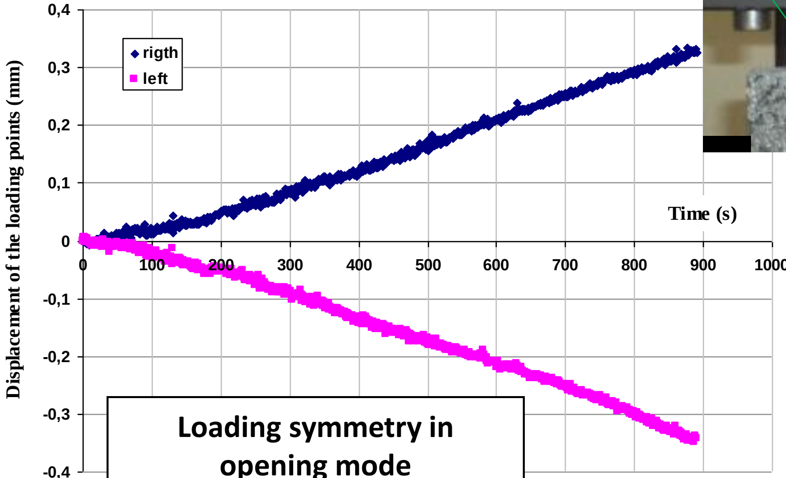
RESULTS

F vs. COD

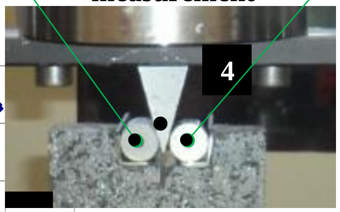


Wedge Splitting Test

Loading points displacement



Black marks for COD measurement

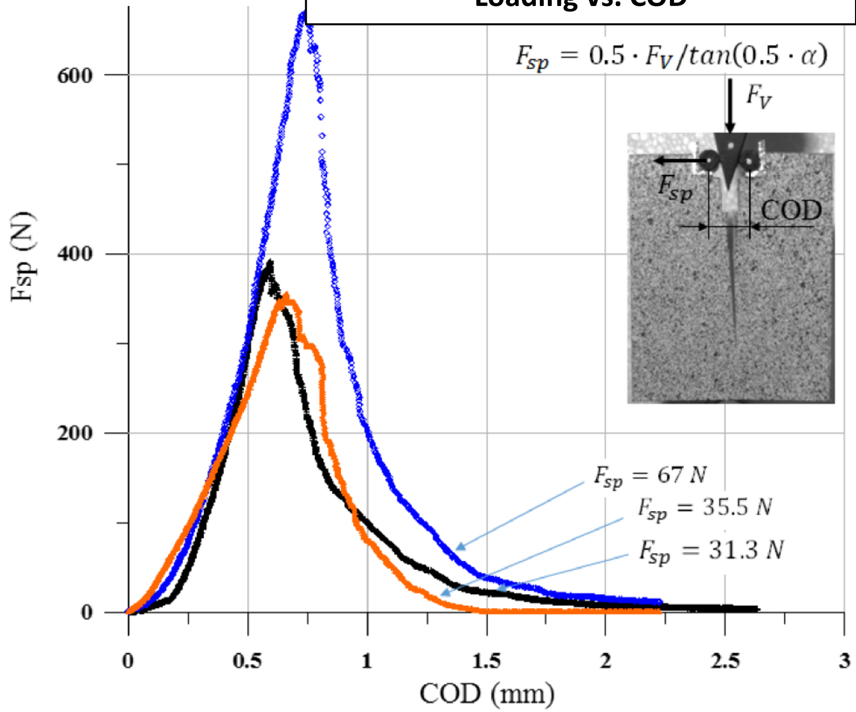


Loading symmetry in opening mode

$$Work\ of\ frature = \int_0^{COD} F_{sp} \cdot d(COD)$$

$$G_F = \frac{Work\ of\ fracture}{A_f}$$

Loading vs. COD

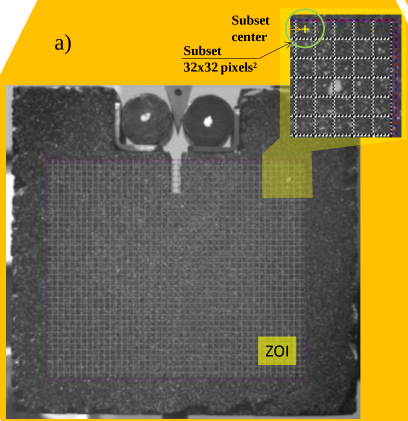


Samples	Work of fracture (N.mm)	Fracture energy (J/m²)
Génotype A	94.42	163.85
Génotype B	273.80	326.12
Génotype C	174.50	269.62

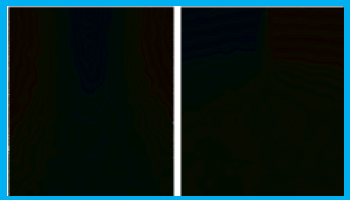
RESULTS

Optical measurements

DIC measurement and analysis

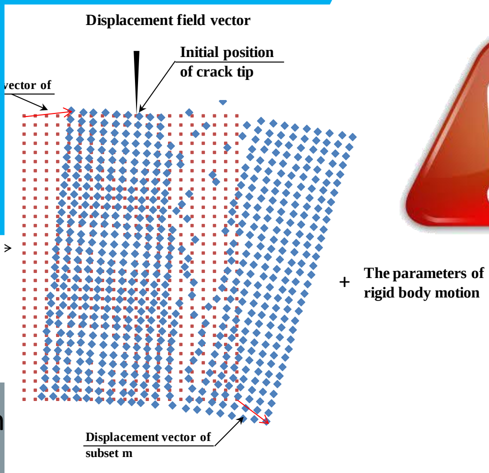


Experimental approach

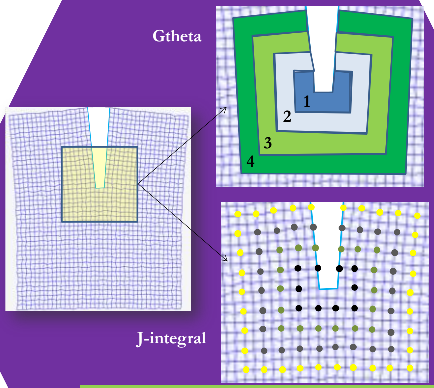


Experimental noised Rigid Body Motions

Displacement field cartographies

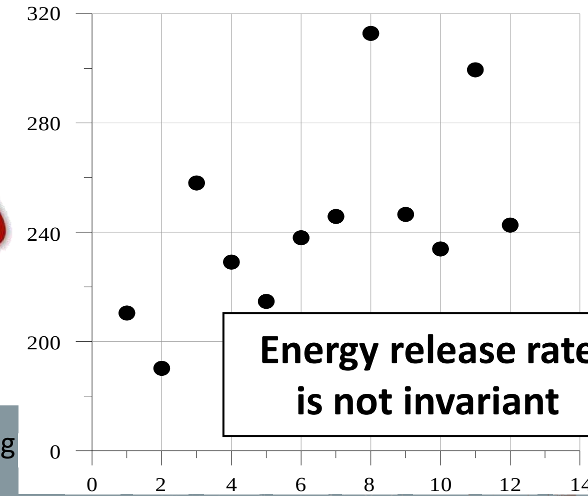


Energy release rate



+ Constitutive law

Numerical approach



Energy release rate is not invariant

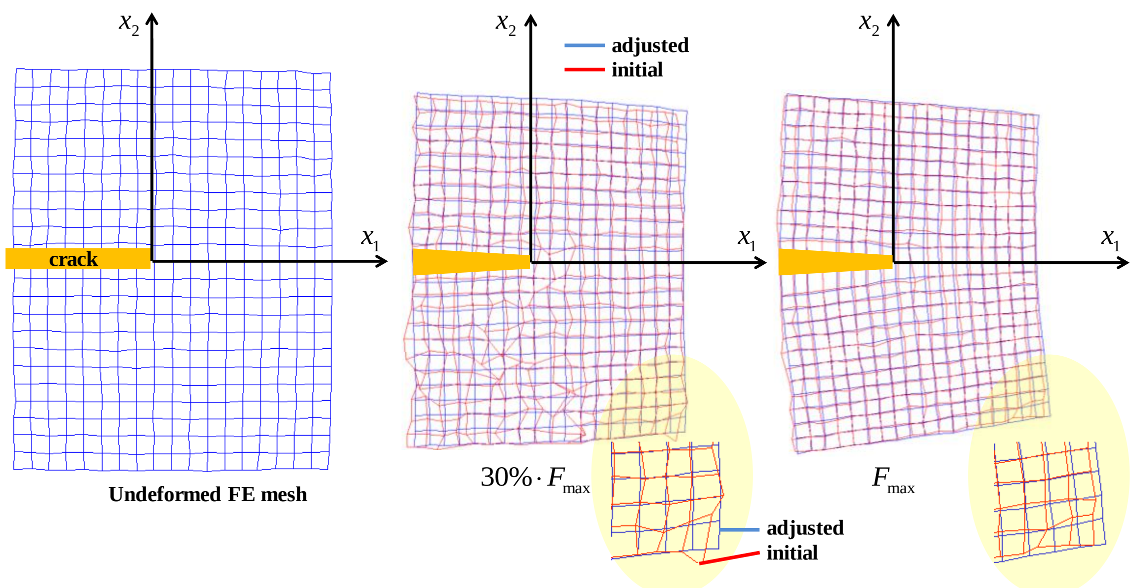
RESULTS

Optimization of displacement fields

$$u_1 = \sum_{\chi=1}^{N}\left(A_1^{\chi}\cdot r^{(\chi/2)}\cdot f_{\chi}(\kappa,\varphi)+A_2^{\chi}\cdot r^{(\chi/2)}\cdot g_{\chi}(\kappa,\varphi)\right)$$

$$u_2 = \sum_{\chi=1}^{N}\left(A_1^{\chi}\cdot r^{(\chi/2)}\cdot l_{\chi}(\kappa,\varphi)+A_2^{\chi}\cdot r^{(\chi/2)}\cdot z_{\chi}(\kappa,\varphi)\right)$$

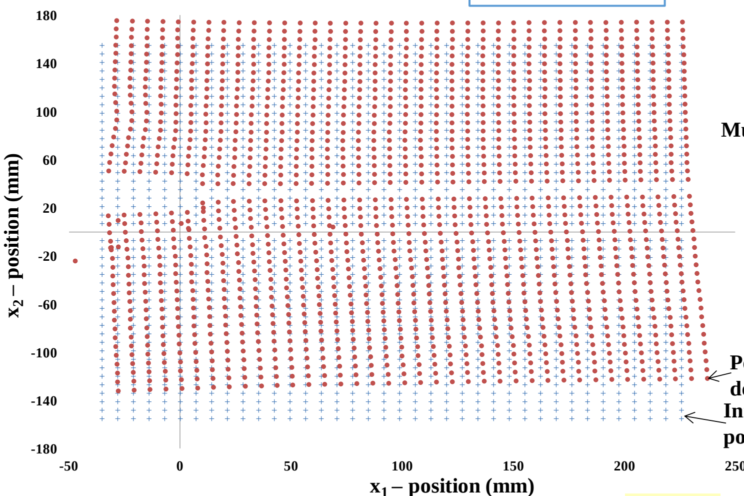
Optimization of displacement field ≡ By an adjustment procedure



RESULTS

Optimization of displacement fields

Amplification x50



Muskhelishvili series weighting coefficients

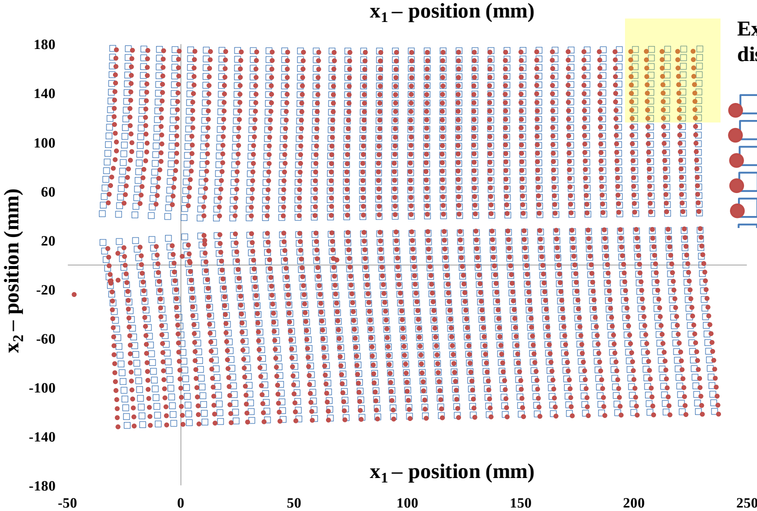
1,24E-02	$mm^{1/2}$	A11
2,41E-04	mm	A12
-4,02E-05	$mm^{3/2}$	A13
-7,00E-07	mm^2	A14
1,00E-07	$mm^{5/2}$	A15

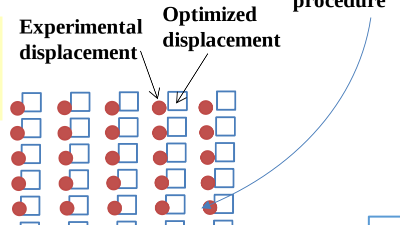
$$u_1 = \sum_{\chi=1}^{N}\left(A_1^{\chi} \cdot r^{(\chi/2)} \cdot f_{\chi}(\kappa,\varphi) + A_2^{\chi} \cdot r^{(\chi/2)} \cdot g_{\chi}(\kappa,\varphi)\right)$$

$$u_2 = \sum_{\chi=1}^{N}\left(A_1^{\chi} \cdot r^{(\chi/2)} \cdot l_{\chi}(\kappa,\varphi) + A_2^{\chi} \cdot r^{(\chi/2)} \cdot z_{\chi}(\kappa,\varphi)\right)$$

Rigid body movements

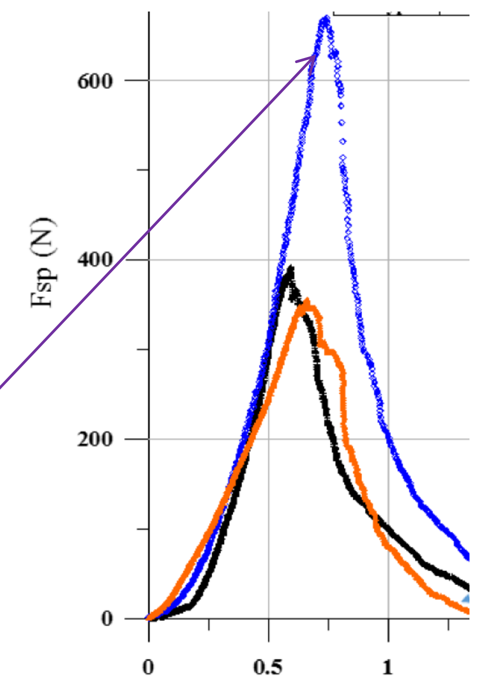
0,023	mm	Translation x1
1,546	mm	Translation x2
0,001	rad	Rotation





c)

F = 90% F_{max}



RESULTS

New formalism

Equivalent displacement field from adjustment procedure

$$K_{\alpha}^{(\varepsilon)} = C_{\alpha} \cdot K_{\alpha}^{(\sigma)}$$

Crack relative displacement factors

Dubois et al.

$$K_1^{(\varepsilon)} = 2 \cdot \sqrt{2 \cdot \pi} \cdot A_1^1 \cdot (\kappa + 1)$$

$$K_2^{(\varepsilon)} = -2 \cdot \sqrt{2 \cdot \pi} \cdot A_2^1 \cdot (\kappa + 1)$$

$$u_1 = \sum_{\chi=1}^{N} \left(A_1^{\chi} \cdot r^{(\chi/2)} \cdot f_{\chi}(\kappa, \varphi) + A_2^{\chi} \cdot r^{(\chi/2)} \cdot g_{\chi}(\kappa, \varphi) \right)$$

$$u_2 = \sum_{\chi=1}^{N} \left(A_1^{\chi} \cdot r^{(\chi/2)} \cdot l_{\chi}(\kappa, \varphi) + A_2^{\chi} \cdot r^{(\chi/2)} \cdot z_{\chi}(\kappa, \varphi) \right)$$

Reduced elastic compliance

$$C_{\alpha}$$

Stress intensity factor

$$K_I^{\sigma}$$

$$K_1^{(\sigma)} = \frac{F_{sp}}{B \cdot \sqrt{W}} \cdot \frac{2 + \frac{a}{W}}{\left(1 - \frac{a}{W}\right)^{1.5}} \cdot f_1\left(\frac{a}{W}\right)$$

$$G = \frac{\left(K_I^{(\sigma)}\right)^2}{E}$$

Energy release rate

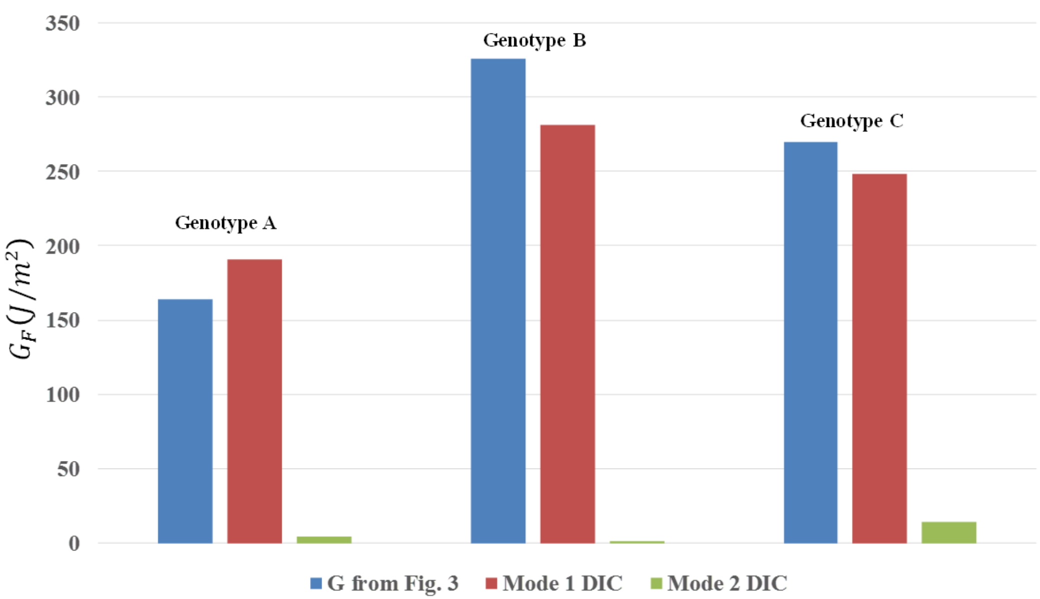
New approach

$$G_{\alpha} = \frac{K_{\alpha}^{(\sigma)} \cdot K_{\alpha}^{(\varepsilon)}}{8}$$

RESULTS

Fracture parameters corresponding to critical splitting force

Génotype	F_{sp} (N)	K^e_1 ($mm^{0.5}$)	K^e_2 ($mm^{0.5}$)	K^s_1 ($Mpa.mm^{0.5}$)	K^s_2 ($Mpa.mm^{0.5}$)	G_F (J/m^2)
A	326	0.068	0.0022	22.30	0.72	190.60
B	505	0.094	0.0005	23.80	0.14	281.40
C	282	0.118	0.0070	16.70	0.98	247.94



the fracture energy

Conclusion

❖The objective of this study was to analyse the fracture process by using a coupling between experimental and analytical approaches

❖From a Wedge Splitting Test the fracture parameters were estimated by using the optical measurements

❖Using an adjustment procedure an ‘‘equivalent” displacement field was calculated from the experimental measurements. This procedure allowing the separation of the mixed mode by identifying the part of each mode.

❖The association between the Crack Relative Displacement Factor and the Stress Intensity Factor, allowed us to evaluate the fracture energy without the knowledge of material properties. .

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