A COMPARATIVE STUDY ON THE CRACKING OF TROPICAL WOOD SPECIES BY THE GRID METHOD

B. Odounga[1,2], R. Moutou Pitti[1,3], E. Toussaint[1], M. Grédiac[1]

[1]Université Clermont Auvergne, CNRS, Institut Pascal, Clermont-Ferrand, France
[2]Université des sciences et techniques de Masuku, Franceville, Gabon
[3]CENAREST, IRT, Libreville, Gabon

@ Bernard.Odounga@etudiant.univ-bpclermont.fr

Acknowledgements
This work is partially funded by region Auvergne Rhône-Alpes, ANR (CLIMBOIS grant 13-JS09-0003-01), GDR3544 Sciences du bois and AUGC

Outline

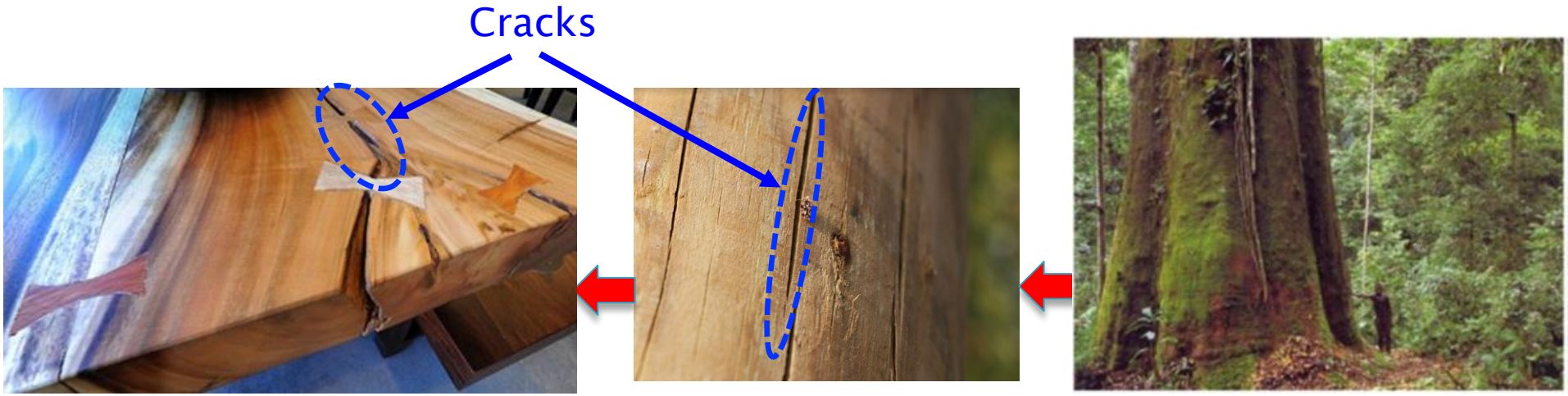
1. Scientific context
2. Experimental setup
3. Results and analysis
4. Conclusion and perspectives

Montivation and challenges

- Wide Gabonese forest (80% of the country)
- Numerous and various species
- Timber structures widely used by locals
- Wood subjected to severe environmental loadings

Aim of this work

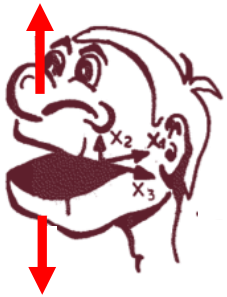
- Studying the fracture of tropical wood under complex mechanical loadings



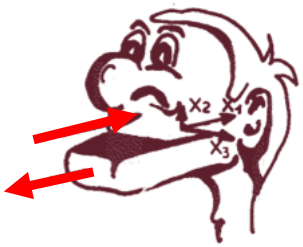
Objective and scientific challenges

- Comparative studies about fracture toughness of tropical species:
  - Iroko (*Milicia excelsa*)
  - Okume (*Aucoumea klaineana*)
  - Padouk (*Pterocarpus soyauxii*)

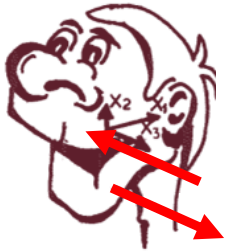
Mode I



Mode II



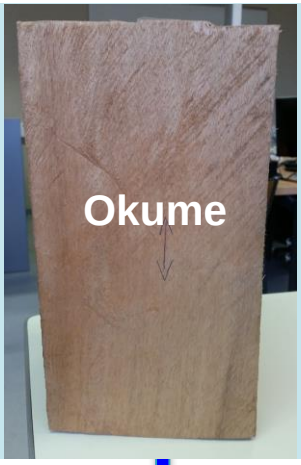
Mode III



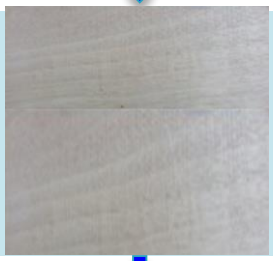
- Application of the Grid method
- Identification of the fracture parameters
- Characterization of cracking in **mixed mode configuration**

Raw wood before machining

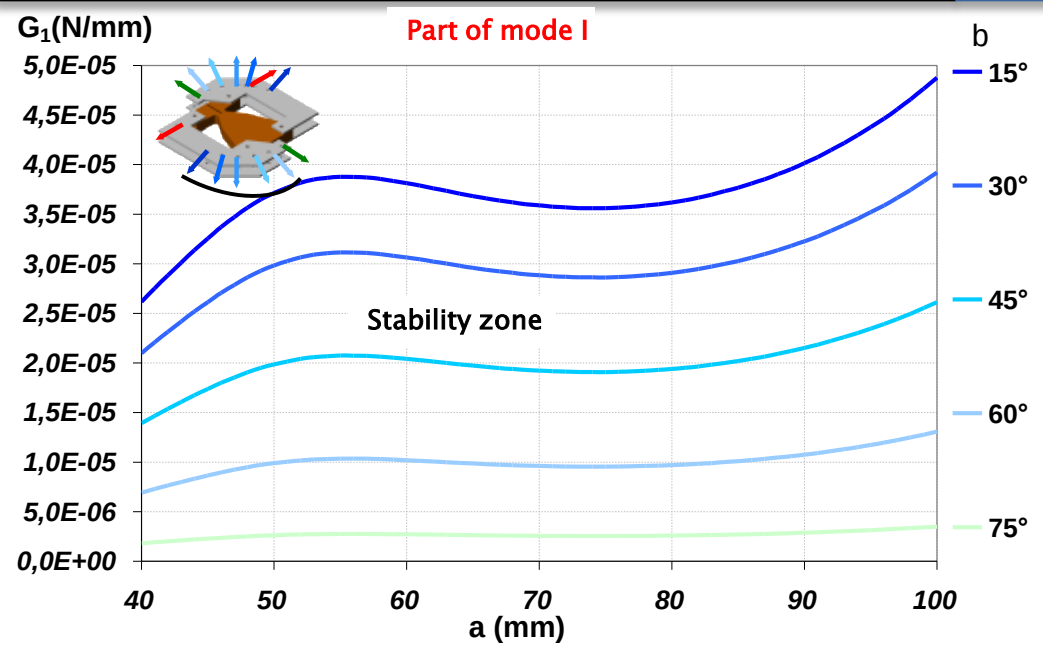
Trunk / species

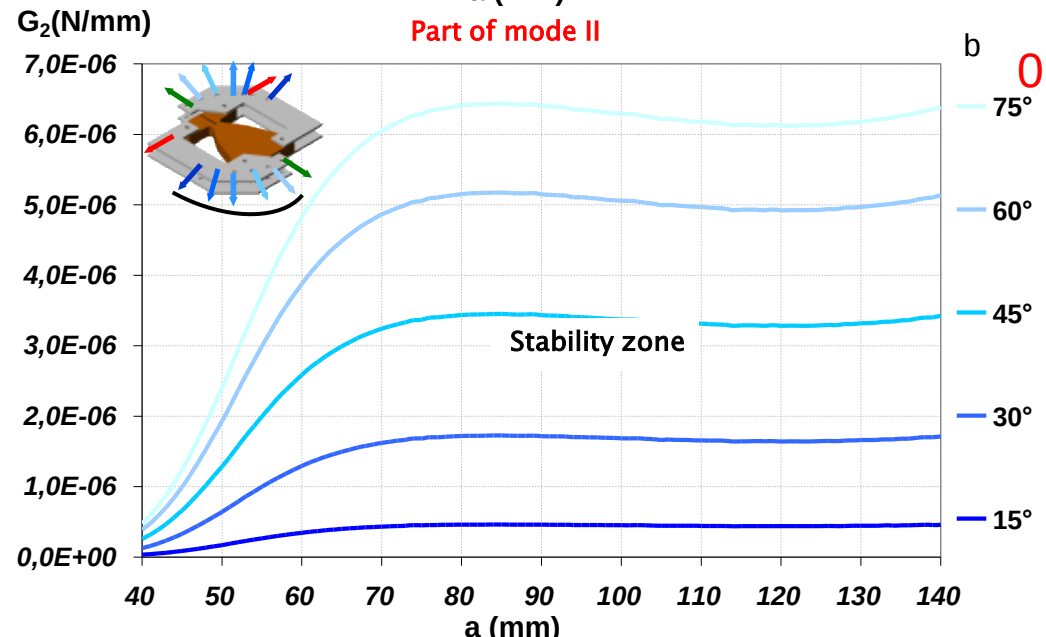


Wood plate

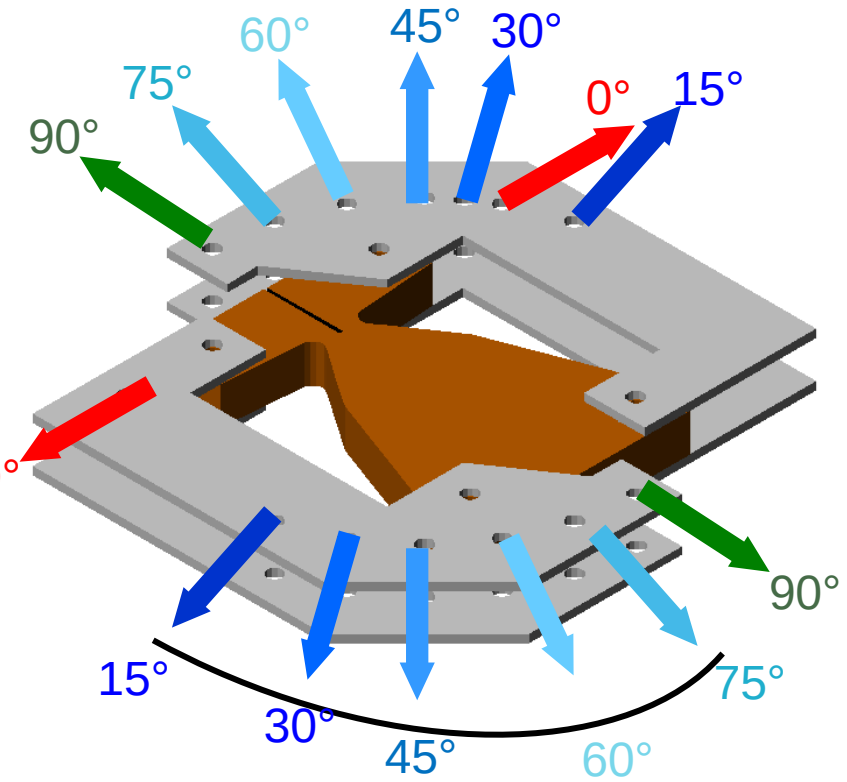


Wood MMCG specimens



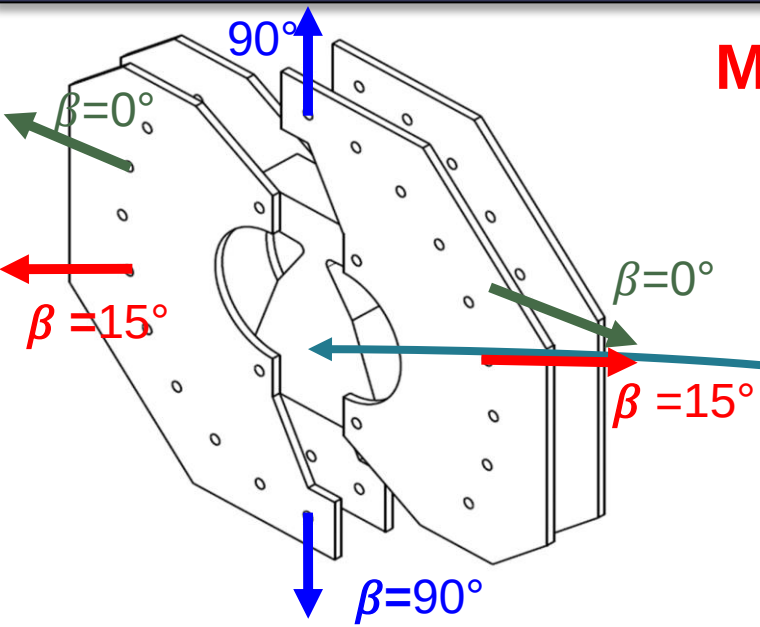


Crack growth stability for various angles β



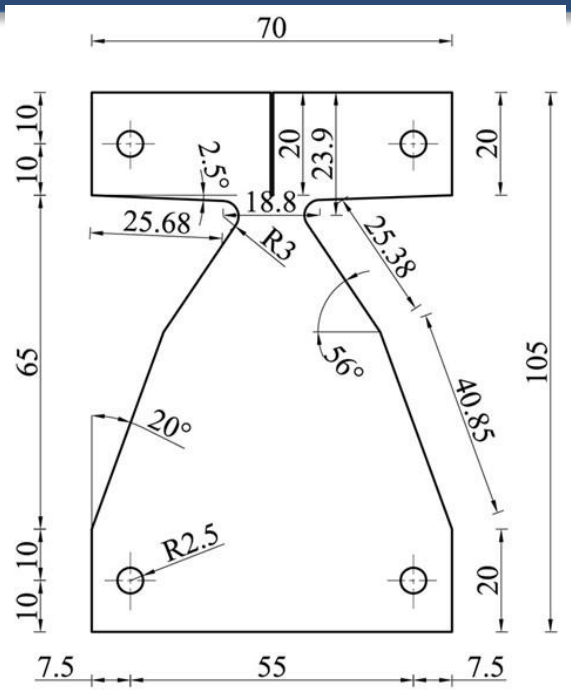
Wood MMCG specimen

Moutou Pitti et al. In. J. Fract. 2011

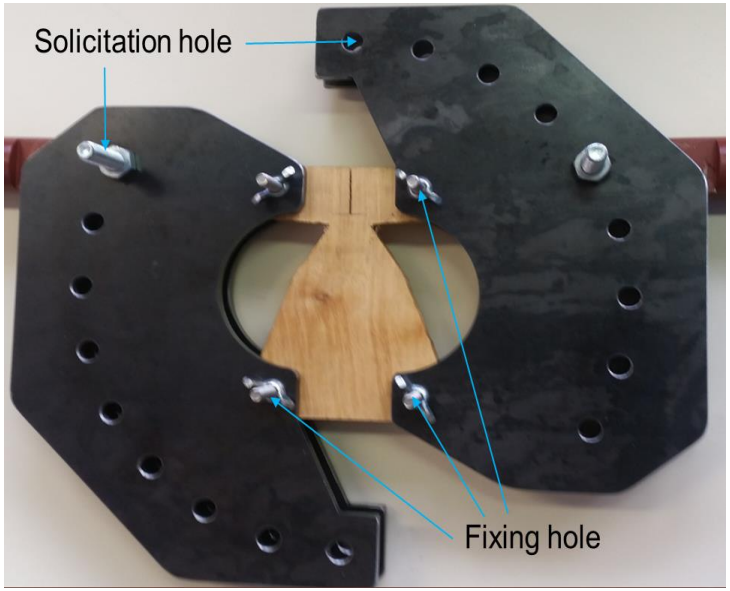


Modified Arcan fixture

MMCG specimen

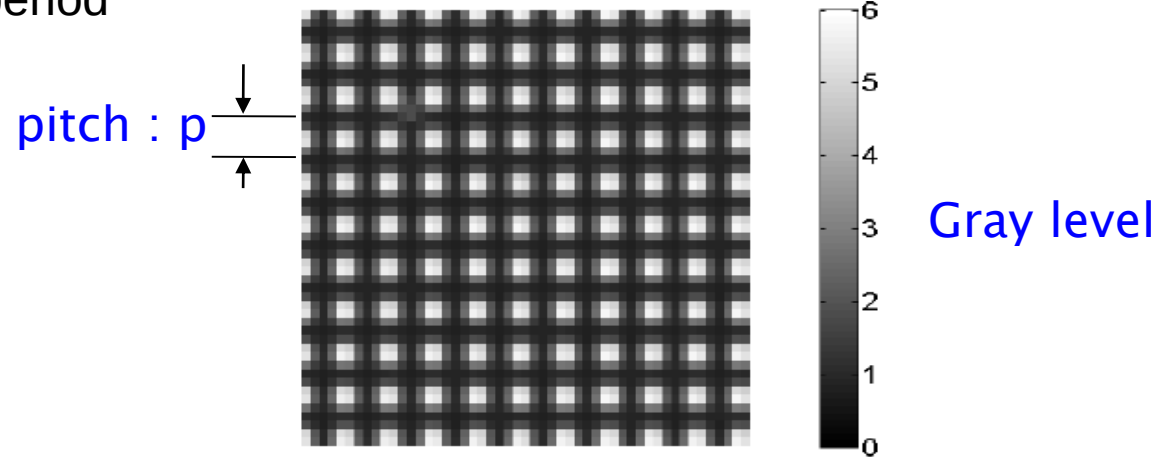


wood specimen



Grid method

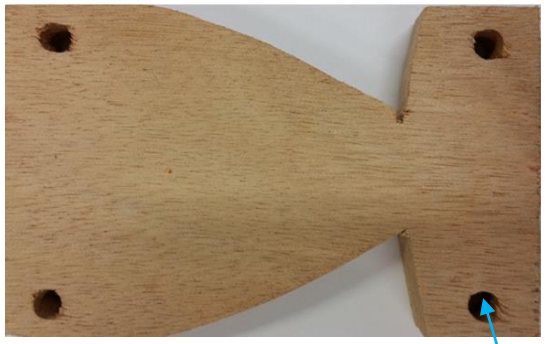
- Crossed grid transferred on the specimen [1]
- Encoding: 5 pixels/period



- p: 200 mm
- Images of the grid are captured before and during loading
- *u* and *ε* fields are deduced from the phases and phase derivatives [2]
- Sensicam camera 1040x1376 pixels, 12bit

[1] Piro J.-L., Grédiac M., **Experimental Techniques**, 28(4):23-26, 2004
[2] C. Badulescu, M. Grédiac, J.-D. Mathias, **Measurement Science and Technology**, 2009

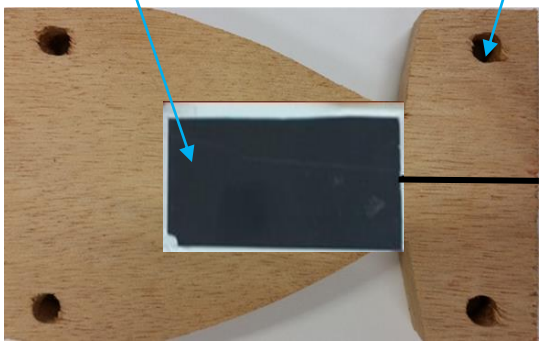
Face without grid



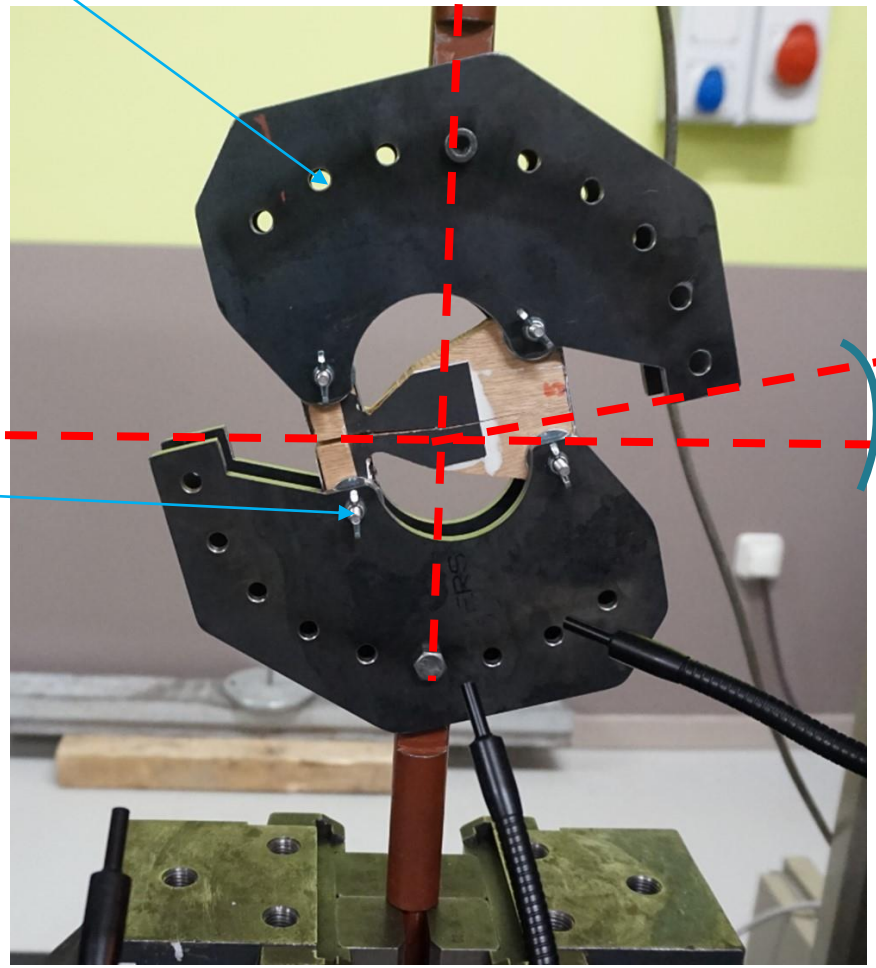
loading hole

Fixing hole

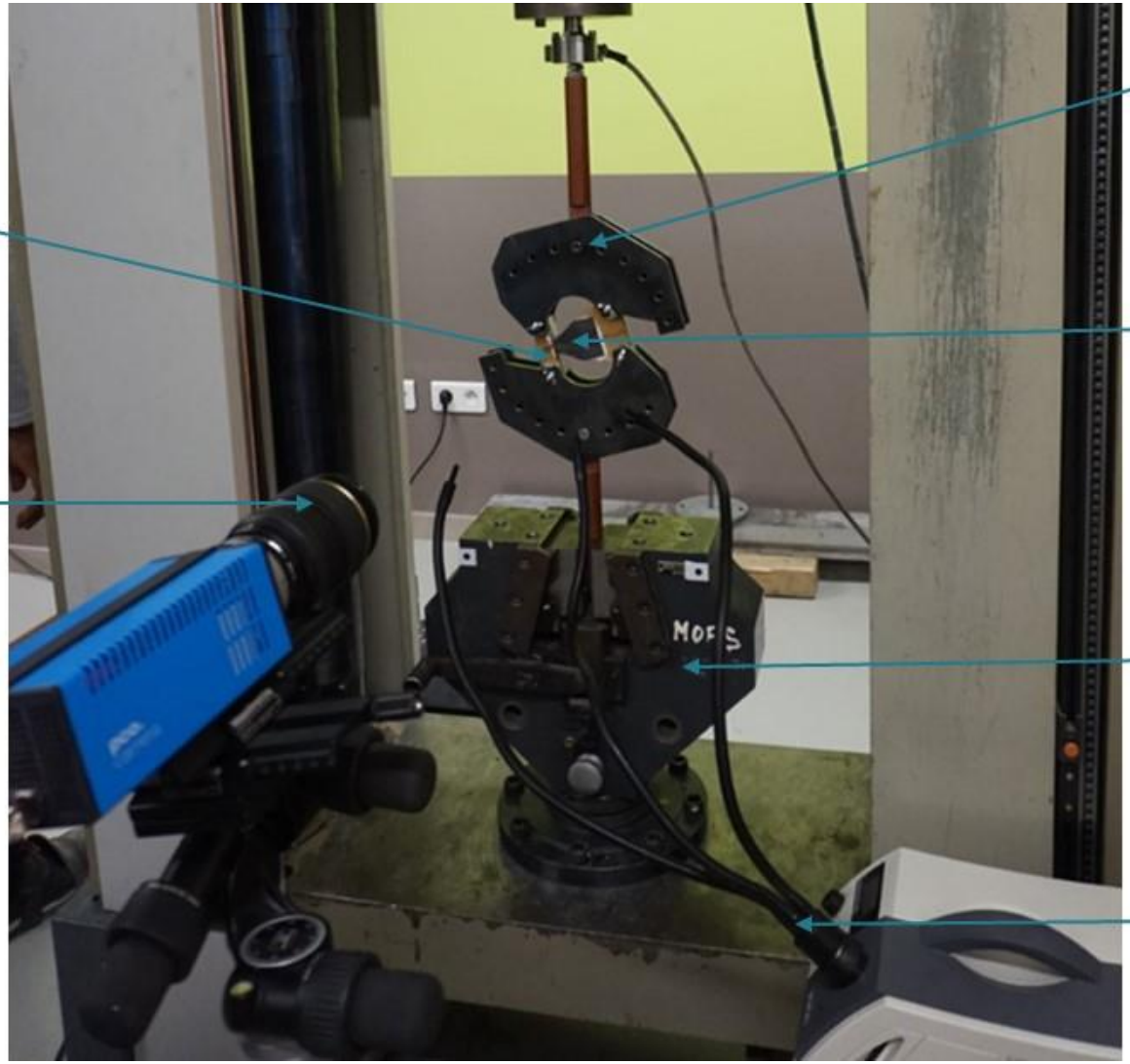
Grid



Face with grid



Wood specimen and fixture



Experimental setup

Mechanical characteristics of the wooden specimens

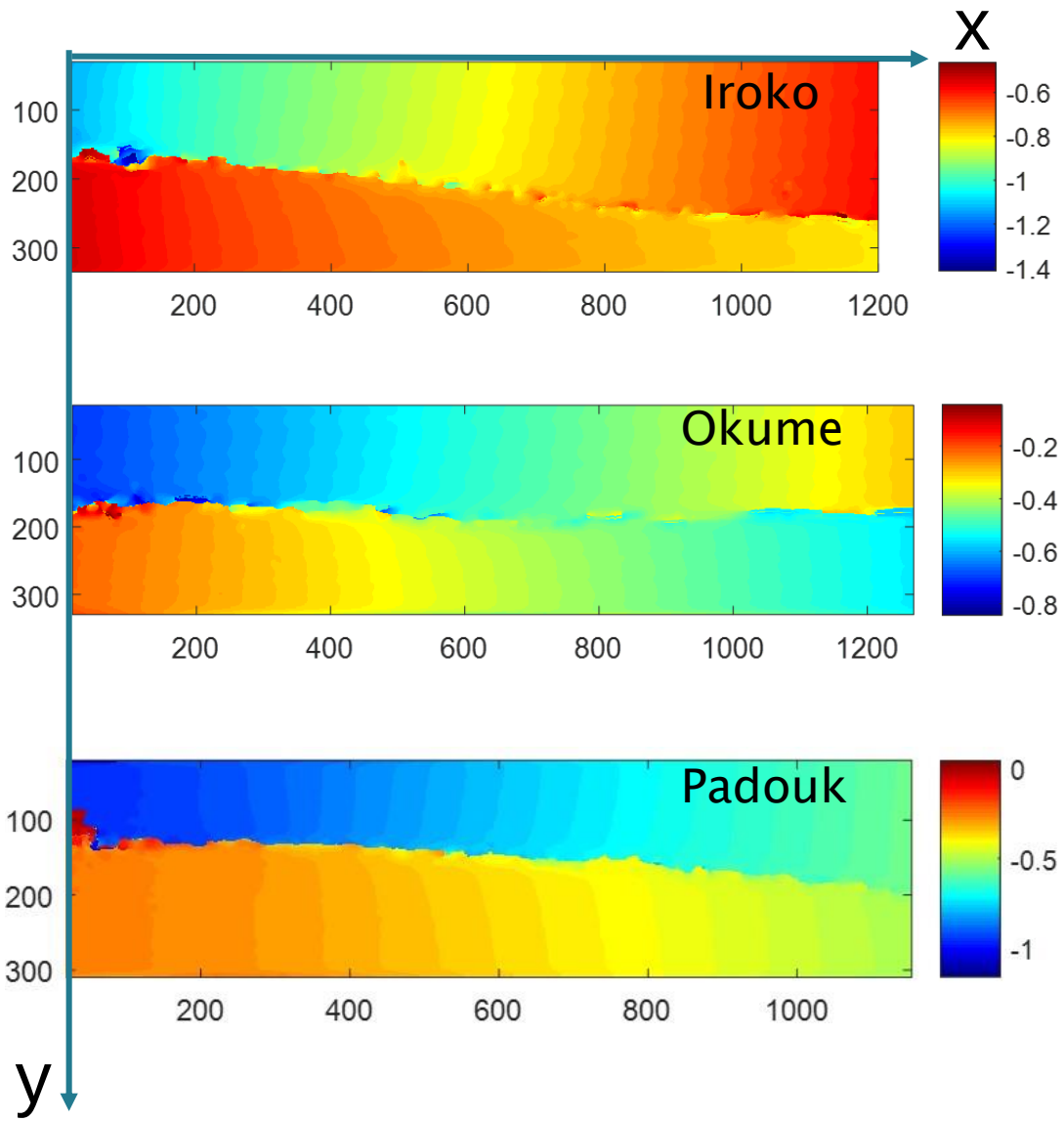
Wood species	Milicia excelsa (Iroko)	Aucumea klaineana (Okume)	Pterocarpus soyauxii (Padouk)
Specimens / e (mm) (Pure opening mode)	IM15 ; IM20	OM15 ; OM20	IM15 ; IM20
Specimens / e (mm) (Mode mixte)	$I1_{20}$; $I2_{20}$	$O1_{20}$; $O2_{20}$	$P1_{20}$; $P2_{20}$
MC (%)	7.94	9.12	7.29
Average density[3]	0.64	0.44	0.79
LMOE (MPa)[3]	12840	9690	15870

I = Iroko; O = Okume; **P** = Padouk **e = 20 mm** : thickness of the specimens

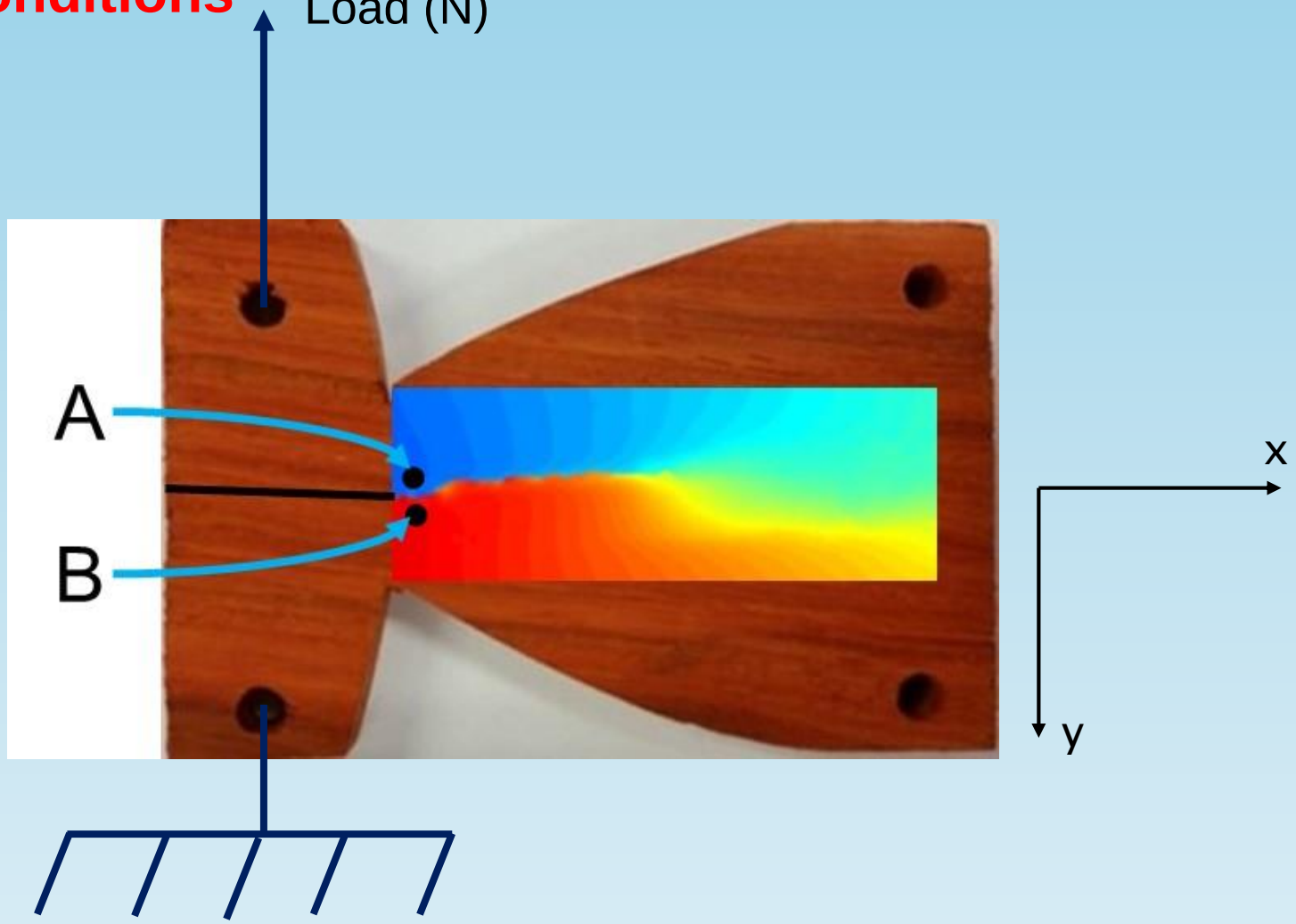
MC = Moisture Content; **LMOE** =Longitudinal Module of Elasticity

[3] CIRAD: Centre de coopération International en Recherche Agronomique pour le développement, TROPIX 7- © 1998-2011.

Typical vertical displacement maps (β =15°, e = 20 mm)

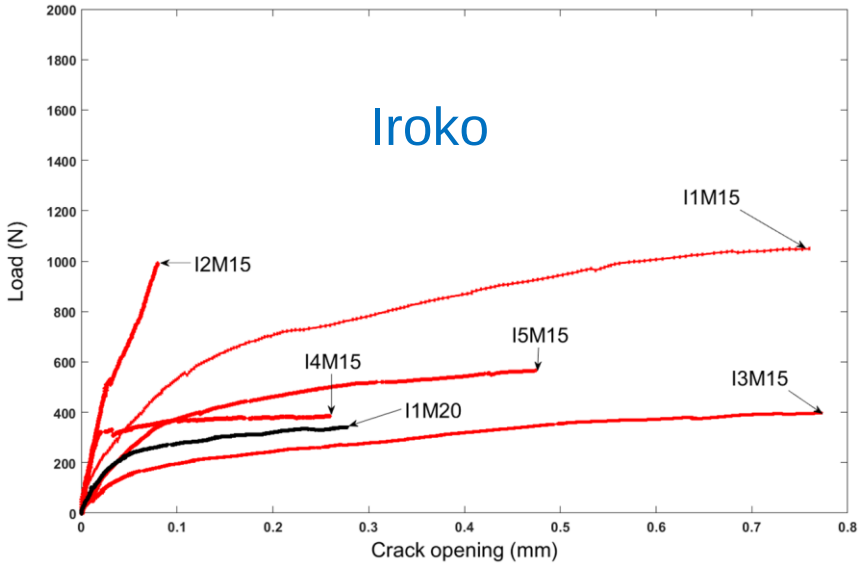


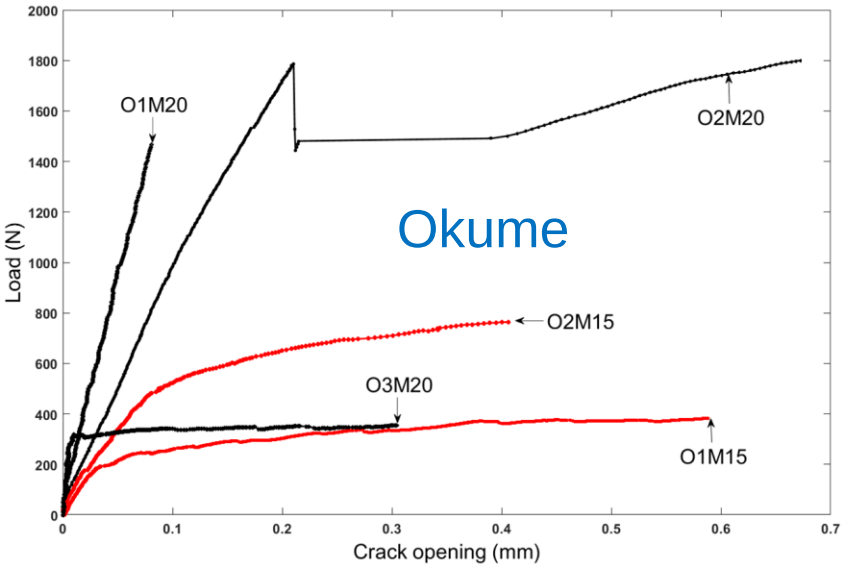
Boundary conditions



Displacement of points A (X, Y_A) and B (X, Y_B) → crack opening

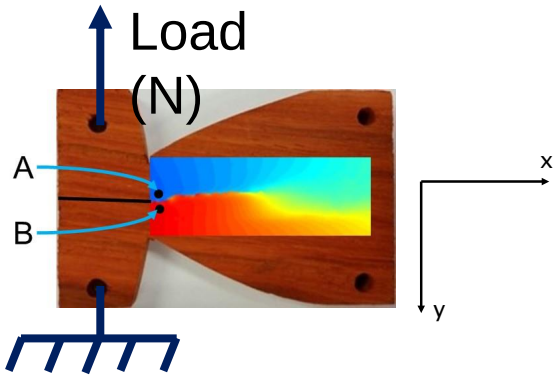
In pure opening mode (β =0°, e = 15 and 20 mm)

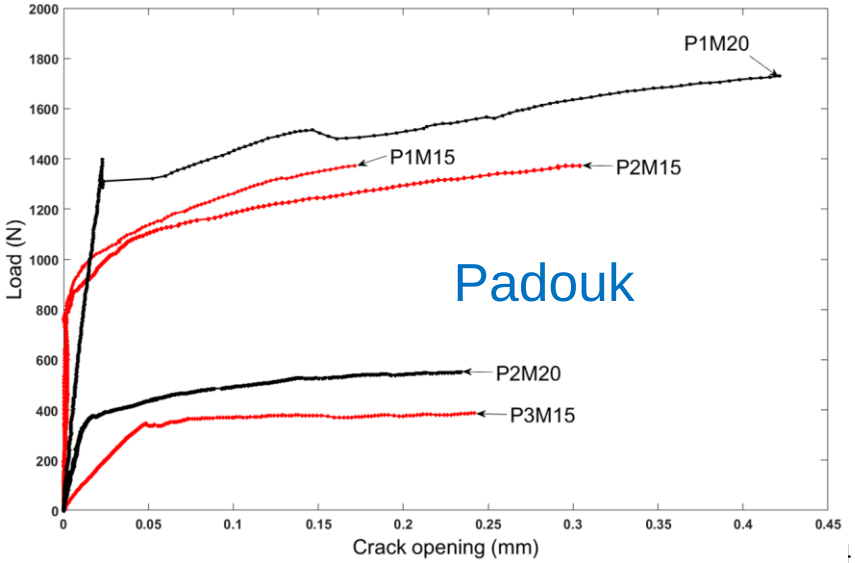




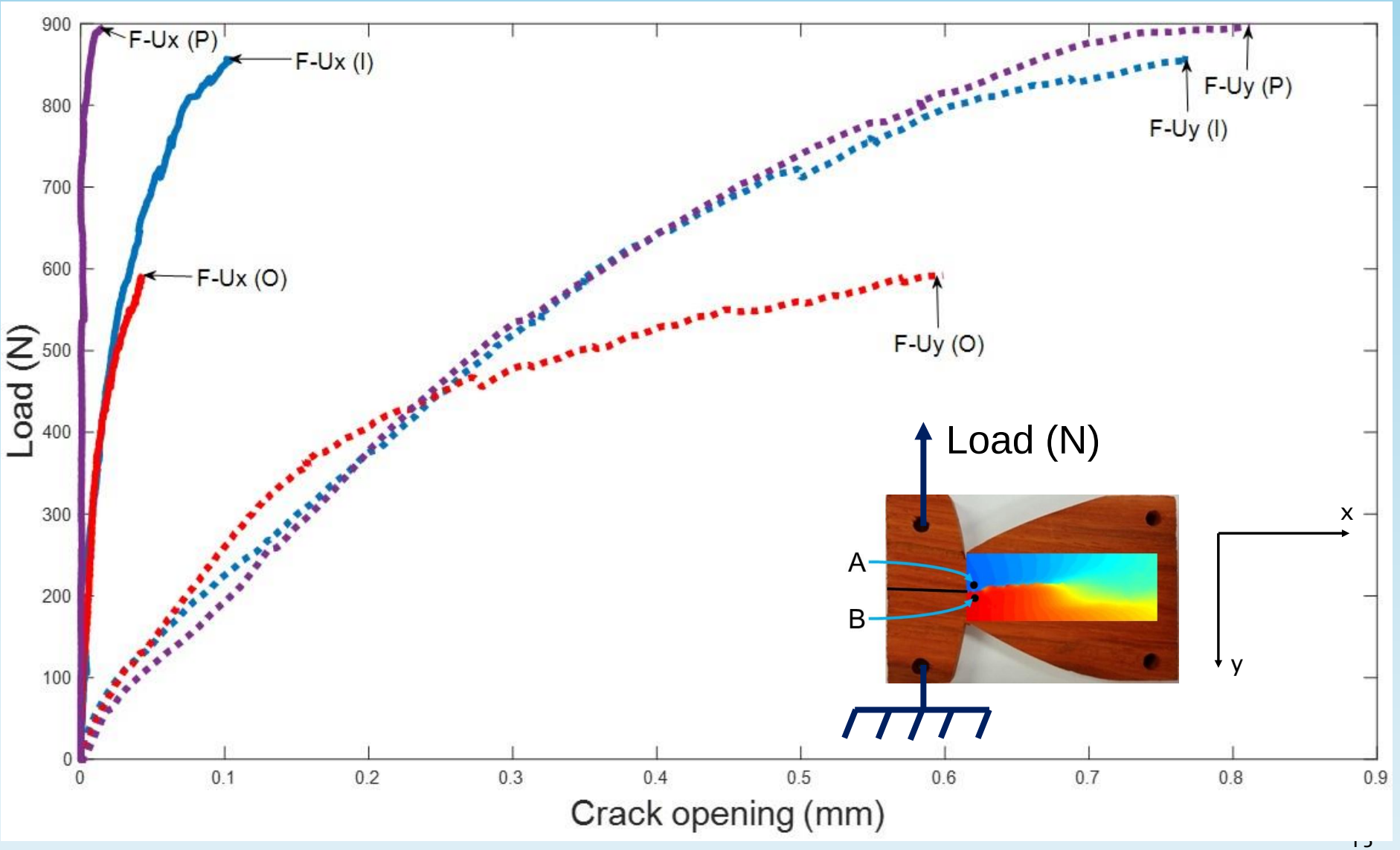
Specimen of thickness 15 mm

Specimen of thickness 20 mm





In mixed mode (β =15°, e = 15 mm)



Compliance method

Critical energy release rate with imposed displacement

$$dC = \frac{dU}{dF}$$

Crack opening

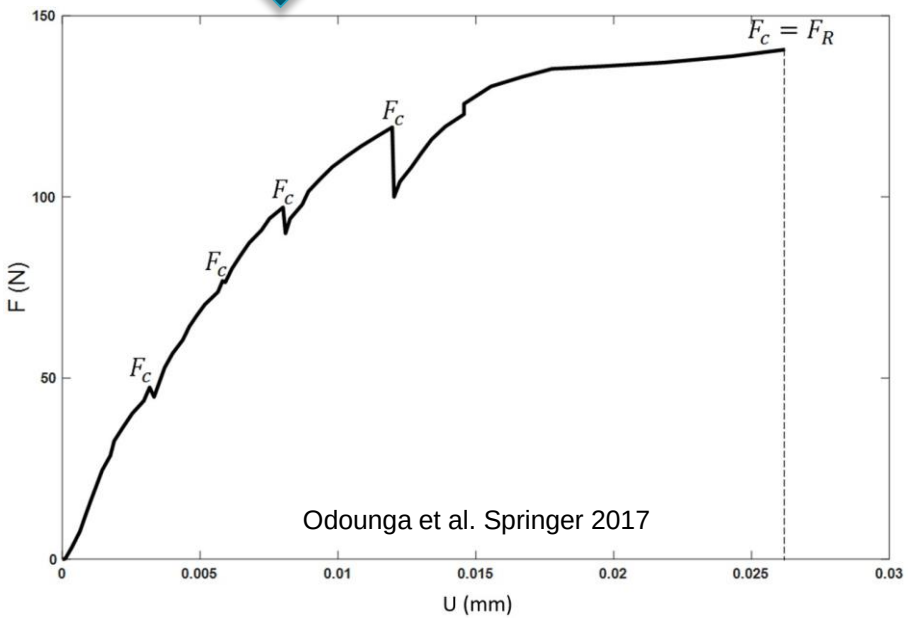
Compliance

$$G_C = \left(\frac{dC}{da}\right)_d \cdot \frac{F_C^2}{2 \cdot b}$$

Critical or fracture load

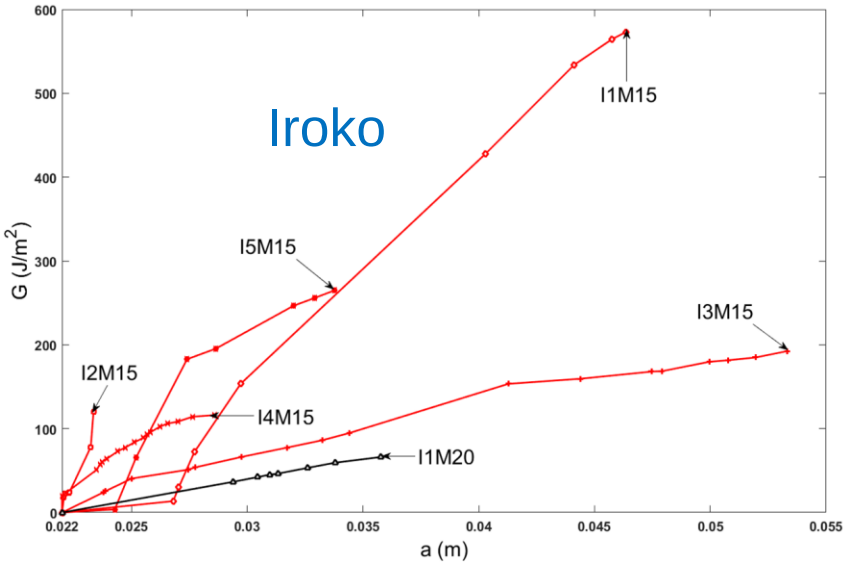
Crack increment

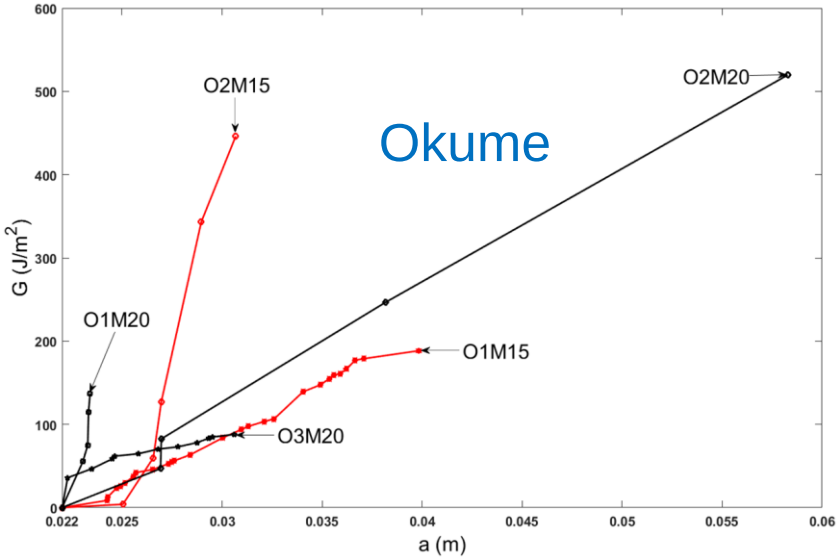
Thickness (e)

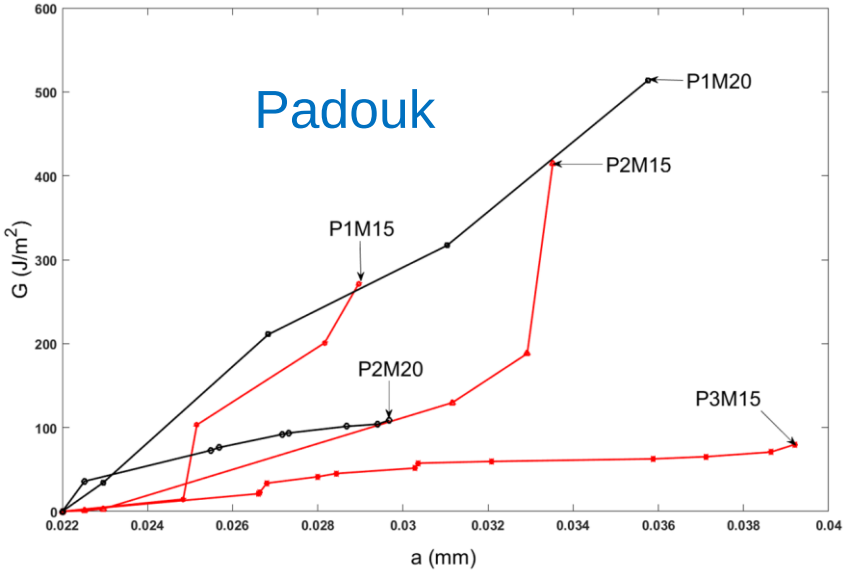


Odounga et al. Springer 2017

Gc vs. crack length in mode I, β =0°



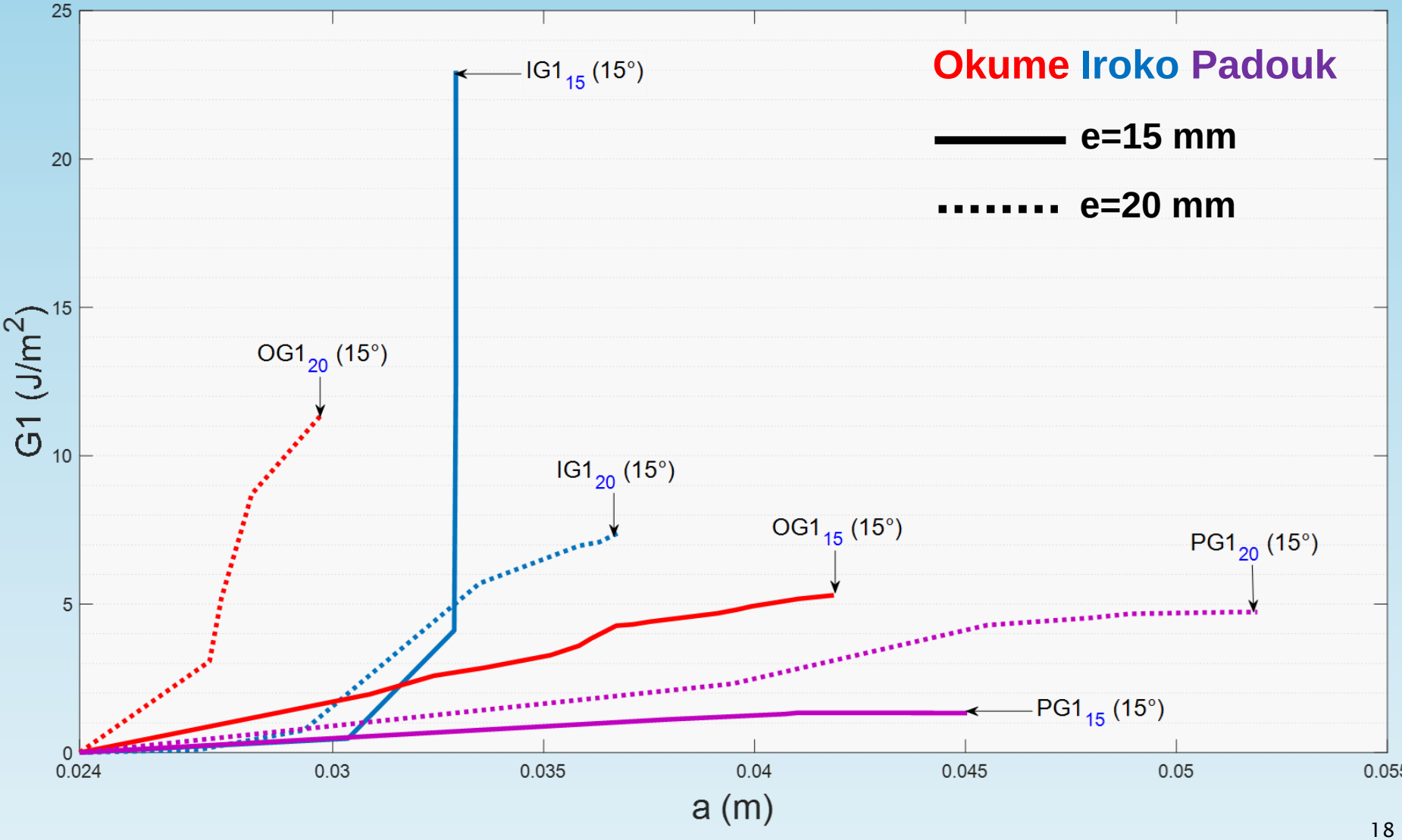




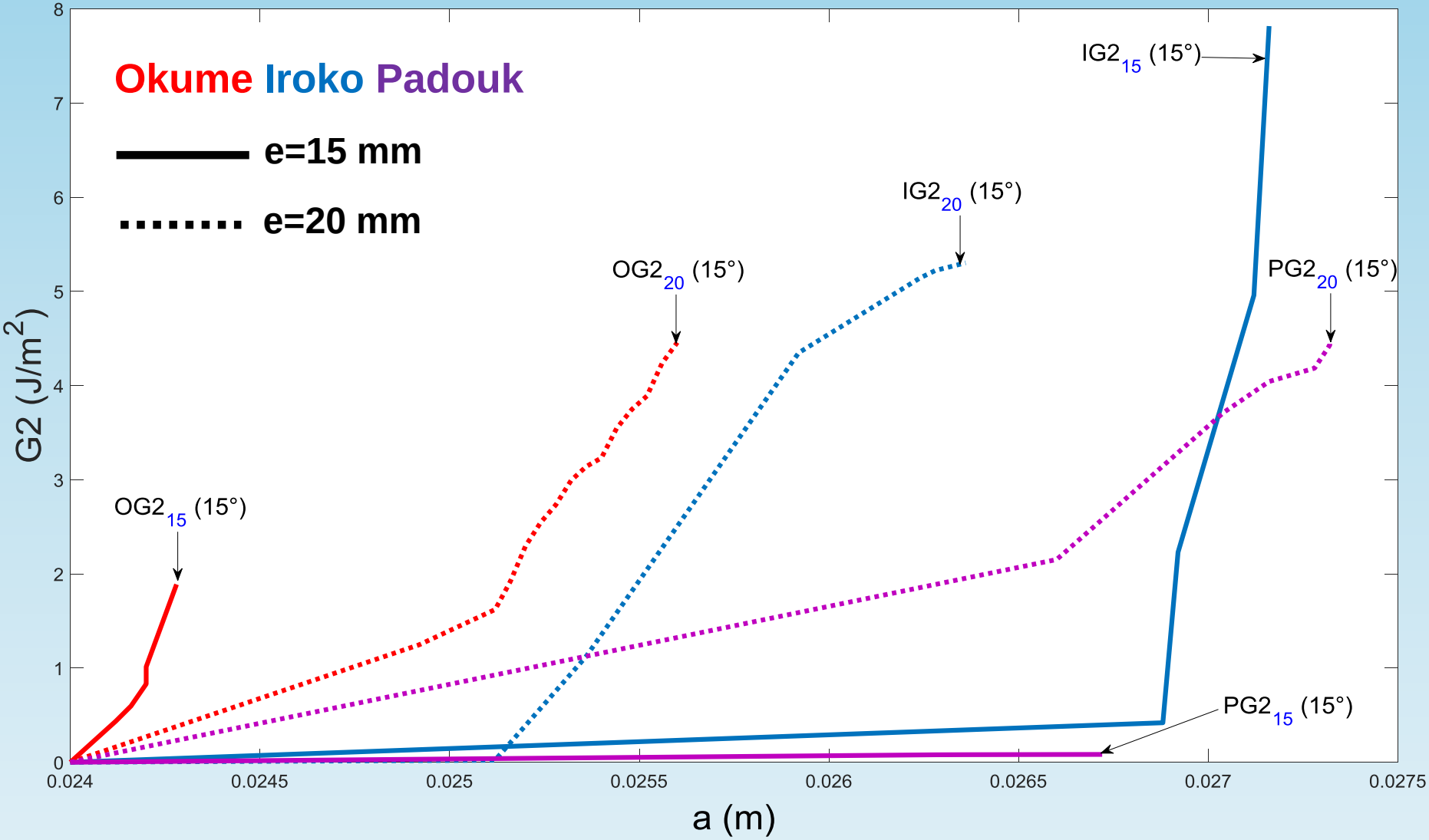
Specimen of thickness 15 mm

Specimen of thickness 20 mm

Part of G1 vs. crack length in mixed mode β =15°



Part of G2 vs. crack length in mixed mode β =15°



Comparison of the Gc of the three species: e= 15 - 20 mm in pure opening mode β =0°

$G_{ic}(J/m^2)$	G_{ic} (*Padouk*)>G_{ic} (*Iroko*)>G_{ic} (*Okume*)
$G_{mc}(J/m^2)$	G_{ic} (*Padouk*)>G_{ic} (*Iroko*)>G_{ic} (*Okume*)

Comparison of the part of G1 and G2 of the three species:

Thicknesses/ Specimens	I_{15} & I_{20} (15°)	O_{15} & O_{20} (15°)	P_{15} & P_{20} (15°)
$G_{ic}(J/m^2)$	$G1_{15} > G1_{20}$ $G2_{15} > G2_{20}$	$G1_{15} < G1_{20}$ $G2_{15} < G2_{20}$	$G1_{15} < G1_{20}$ $G2_{15} < G2_{20}$
$G_{mc}(J/m^2)$	$G1_{15} > G1_{20}$ $G2_{15} > G2_{20}$	$G1_{15} < G1_{20}$ $G2_{15} < G2_{20}$	$G1_{15} < G1_{20}$ $G2_{15} < G2_{20}$

G_{ic} is the initial critical energy release rate

G_{mc} is the maximum critical energy release rate

- Tropical wood, fracture mechanics, grid method
- New Arcan fixture and specific wood MMCG specimen
- Application of the grid method on tropical species
- Visualization of displacement/strains maps and crack
- Results of Gc in mixed mode ratio for 15° and e=15-20 mm
- More experimental tests are necessary
- Tests along the L,R,T directions of wood in mixed mode
- Numerical modeling vs. experimental data

A COMPARATIVE STUDY ON THE CRACKING OF TROPICAL WOOD SPECIES BY THE GRID METHOD

B. Odounga[1,2], R. Moutou Pitti[1,3], E. Toussaint[1], M. Grédiac[1]

[1]Université Clermont Auvergne, CNRS, Institut Pascal, Clermont-Ferrand, France
[2]Université des sciences et techniques de Masuku, Franceville, Gabon
[3]CENAREST, IRT, Libreville, Gabon

@ Bernard.Odounga@etudiant.univ-bpclermont.fr

Acknowledgements
This work is partially funded by region Auvergne Rhône-Alpes, ANR (CLIMBOIS grant 13-JS09-0003-01)
GDR3544 Sciences du bois and AUGC