Composites aéronautique soumis au feu : différents méchanismes de dégradation.

E. Schuhler[a], A. Coppalle[a], B. Vieille[b], J. Yon[a], Y. Carpier[b]

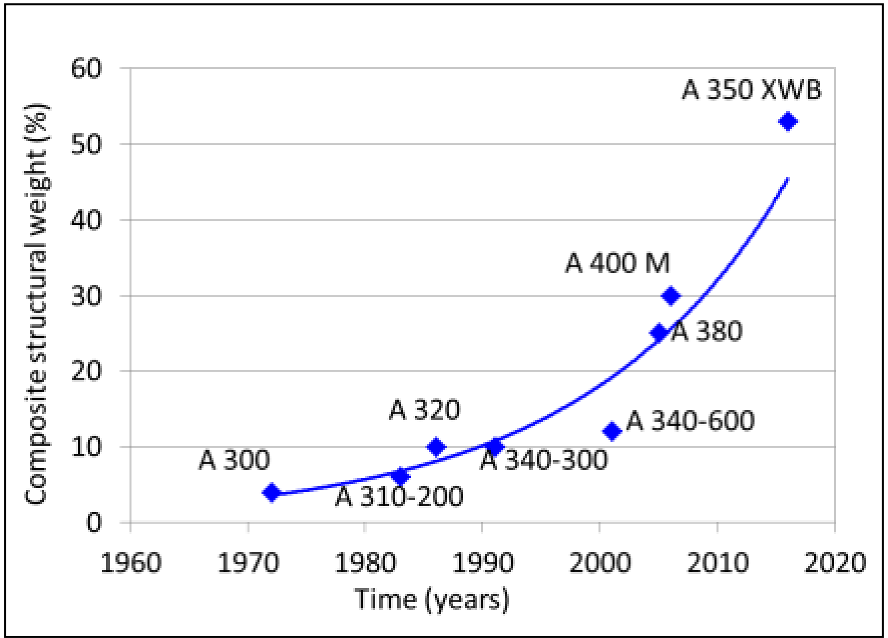
[a] CORIA – UMR 6614 CNRS
[b] GPM – UMR 6634 CNRS
Université et INSA de Rouen

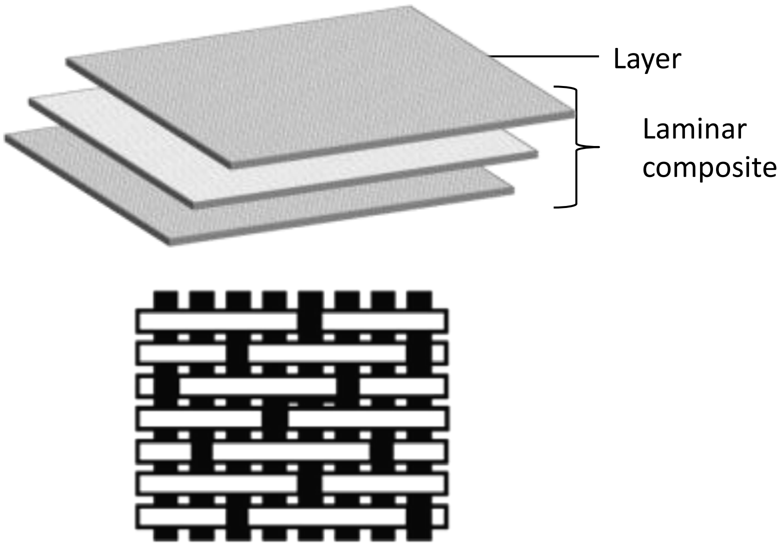
Sommaire

- **Introduction**
- Set up presentation
  - Apparatus
  - Temperature and thermal flux
- Results and discussion
  - In-situ measurements
  - After exposure observations
- Conclusions

- Increasing use of composites in the aeronautical field

- Non homogenous structure
- Anisotropic mechanical and thermal behaviour

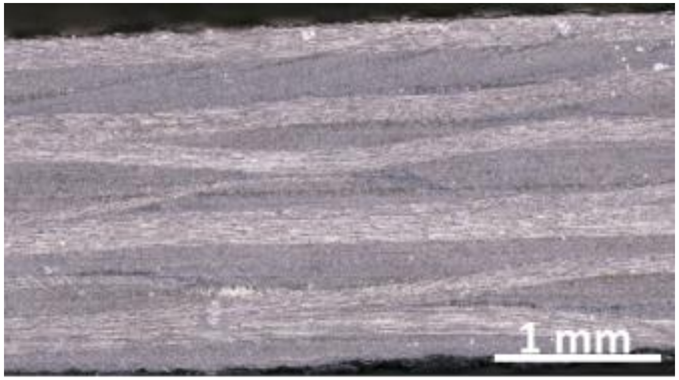




5-harness satin weave

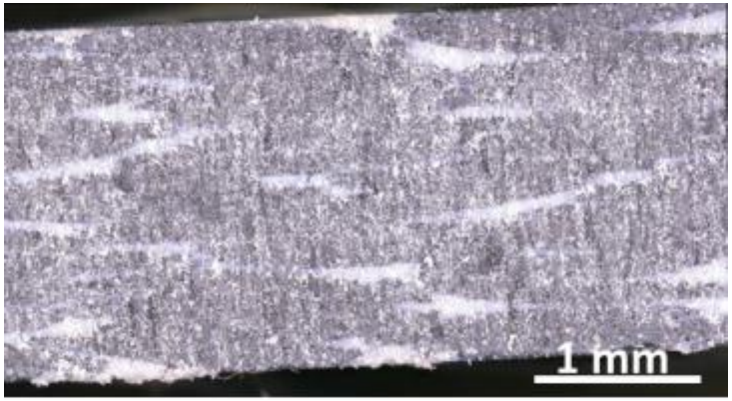
→ **Inflammation risk due to polymer is a safety issue**

→ carbon/thermoset and carbon/thermoplastic materials comparison with high thermal flux : 106kW/m²



Virgin Carbon/Epoxy material

- 2 mm thickness
- Epoxy resin
- $[\pm45]_7$ 5-harness satin weave

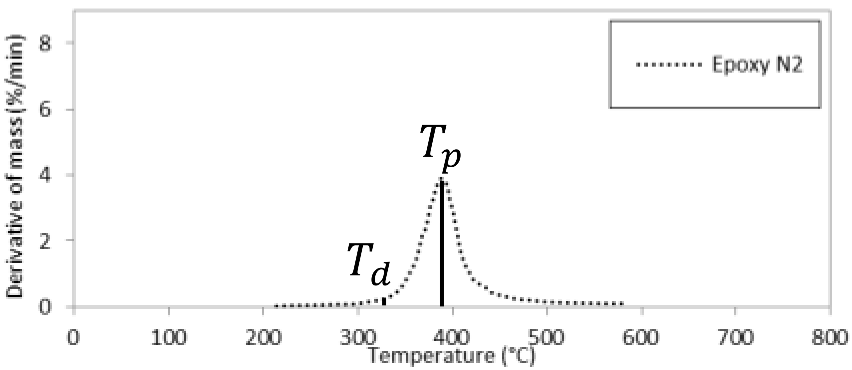


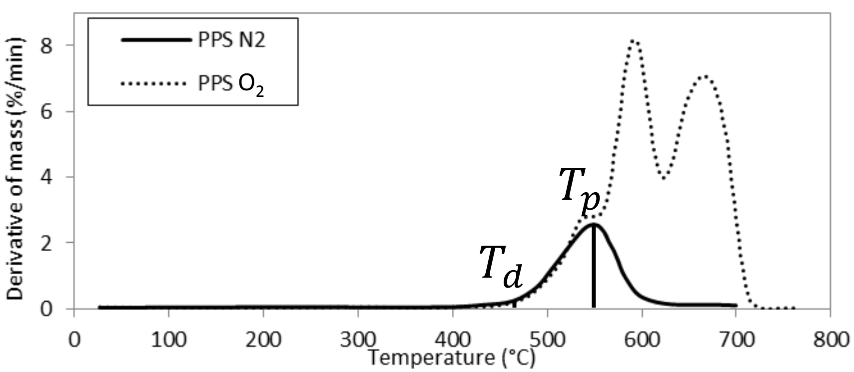
Virgin Carbon/PPS material

- 2.2 mm thickness
- PPS resin
- $[\pm45]_7$ 5-harness satin weave

Introduction
Thermal analysis

- TGA under oxidizing (Air) and non-oxidizing (N2) atmosphere





Vieille et Al. , Materials & Design, 2015

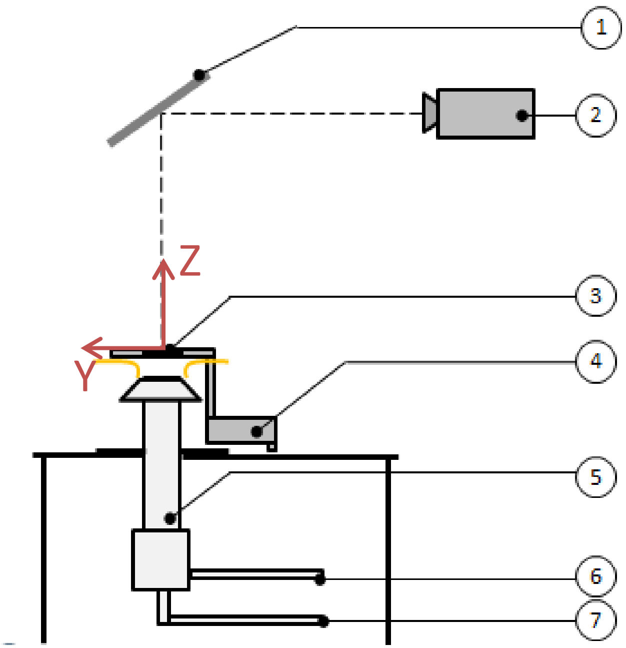
- Epoxy matrix
  - $T_d = 320°C$
  - $T_p = 390°C$

- PPS matrix
  - $T_d = 480°C$
  - $T_p = 550°C$

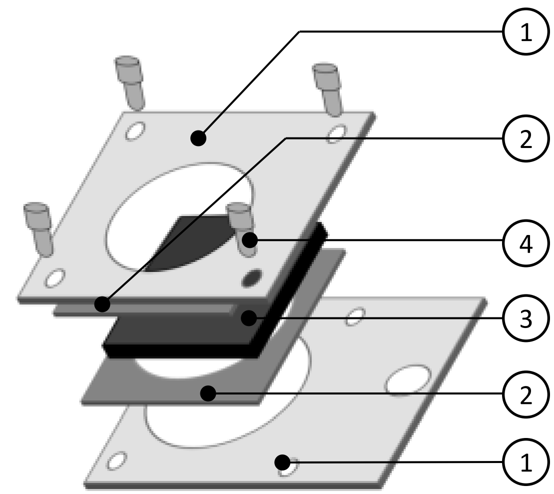
- After 600°C in oxidizing atmosphere the carbon fibres start to deteriorate and lose mass.

  No fibre degradation in N2 environment.

Set up presentation



(1) mirror
(2) infrared camera
(3) coupon
(4) balance
(5) flame burner
(6) air inlet
(7) propane inlet



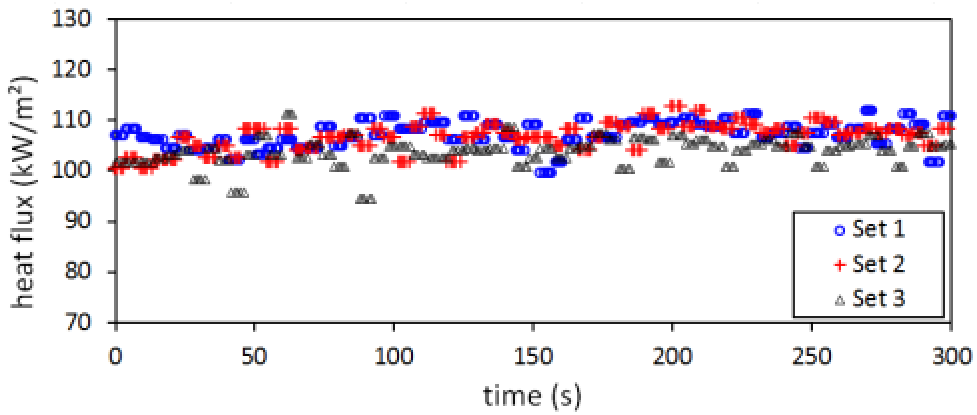
(1) sample holder
(2) insulation sheet
(3) 50x5mm² coupon
(4) screw

- Coupon size : 2 x 50 x 50 mm
- Distance between burner exhaust and coupon surface : 17 mm
- Window size of the sample holder : 45 mm diam.
- Flame at the stoichiometry : non-oxidizing flame

Set up presentation

Thermocouple	X position (mm)	Temperature in the flame (°C)
TC1	-14	940
TC2	-7	1074
TC3	0	1110
TC4	7	1078
TC5	14	950

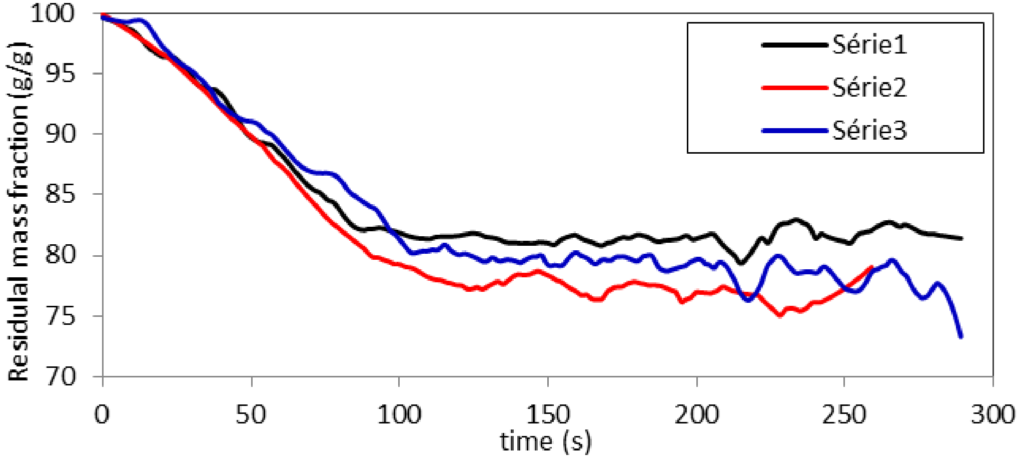
Temperature fluctuation in the flame (σ = 4°C)



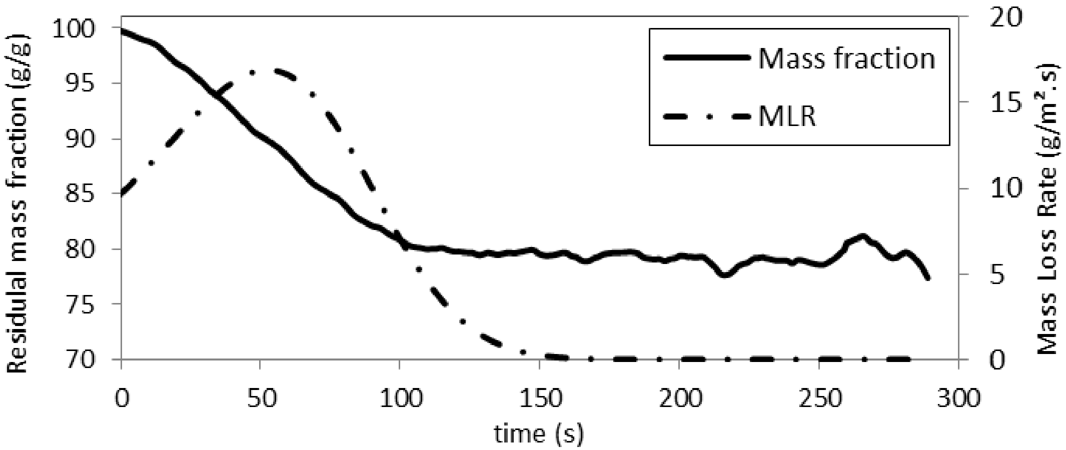
Thermal flux measurement in the center of the flame : goal at 106kW/m²

→ Well-controlled and repeatable heating condition

Method : Mass measurement



Mass measurement for C/Epoxy samples

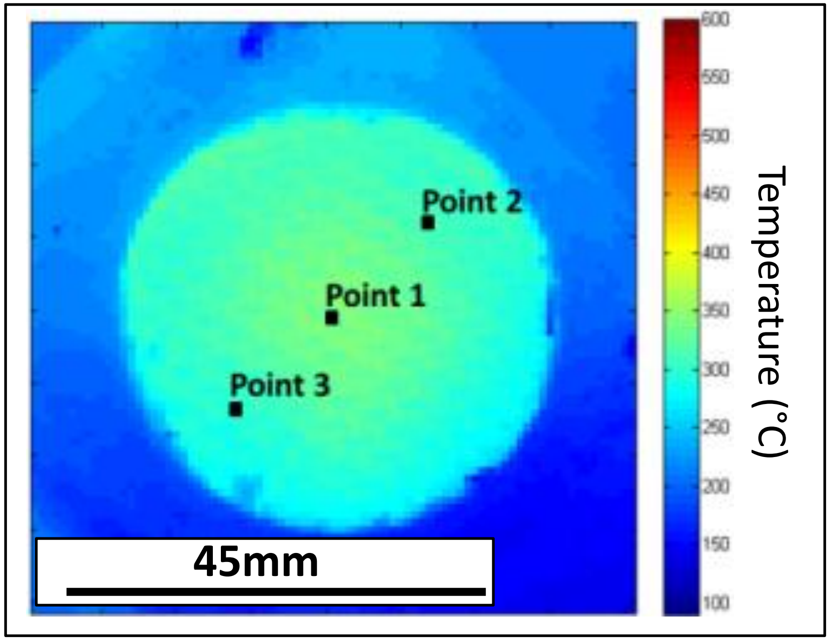


Mean residual mass and MLR for C/Epoxy samples

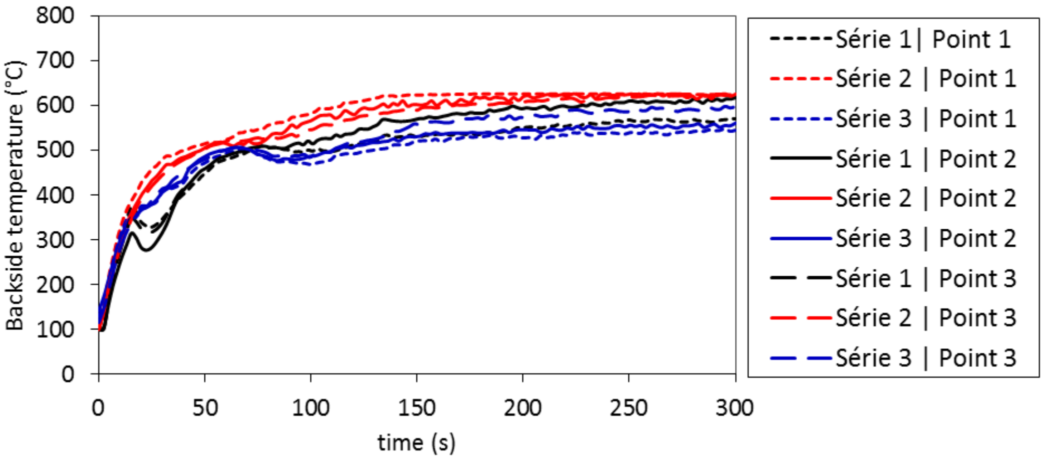
Residual mass and mass loss rate calculation using SawitzkyGolay algorithme for smoothing and first order derivatif calculation.

Staggs, J.E.J., Fire Safety Journal, 2005.

Method : Temperature measurement



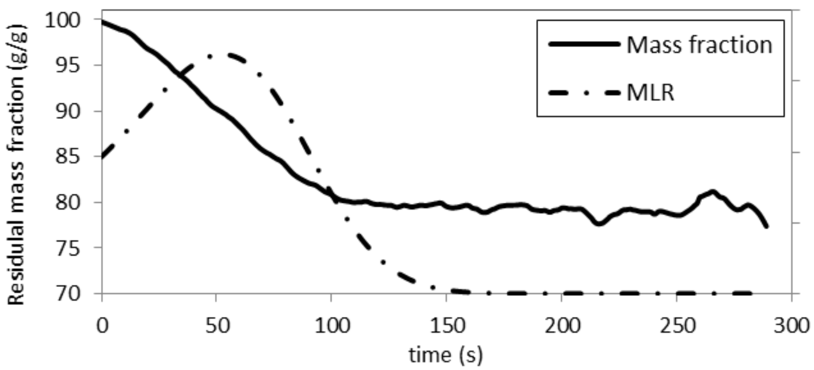
Thermal image from C/Epoxy sample

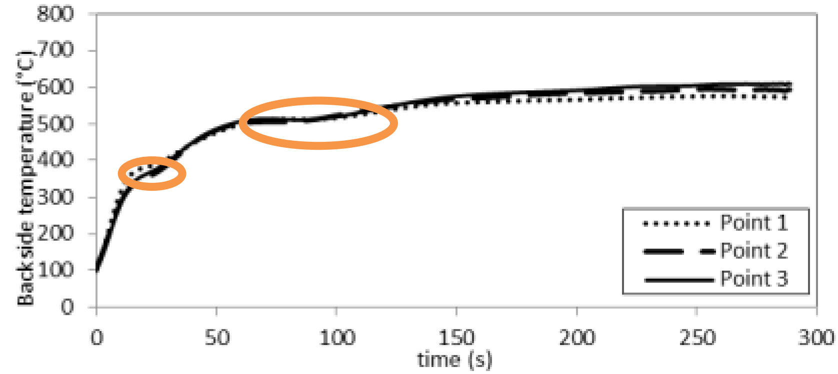


C/Epoxy sample Temperature

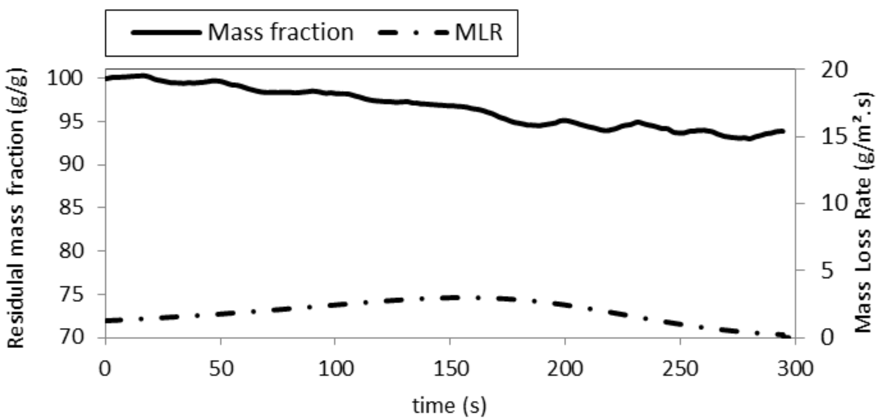
In situ Measurement : Mass loss and temperature

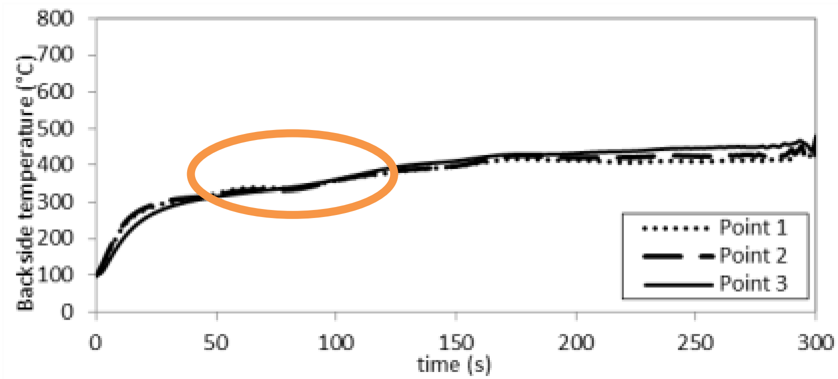
carbon/Epoxy





carbon/PPS



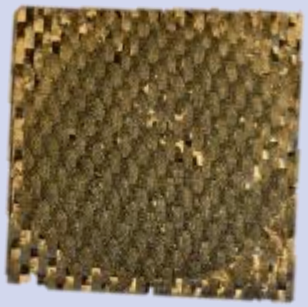


After exposure observations

Observations after a 300 second exposure to the 106kW/m² flame :

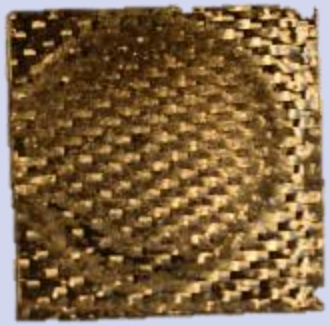
carbon/Epoxy

Back face



Side

Flame face



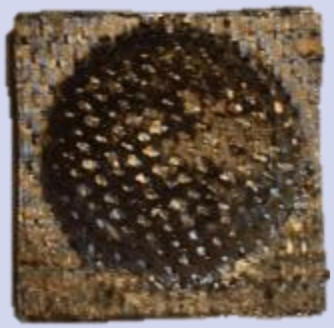
Thickness 3.5 mm
(after degradation)

carbon/PPS

Back face

Side

Flame face



Thickness 9.3 mm
(after degradation)

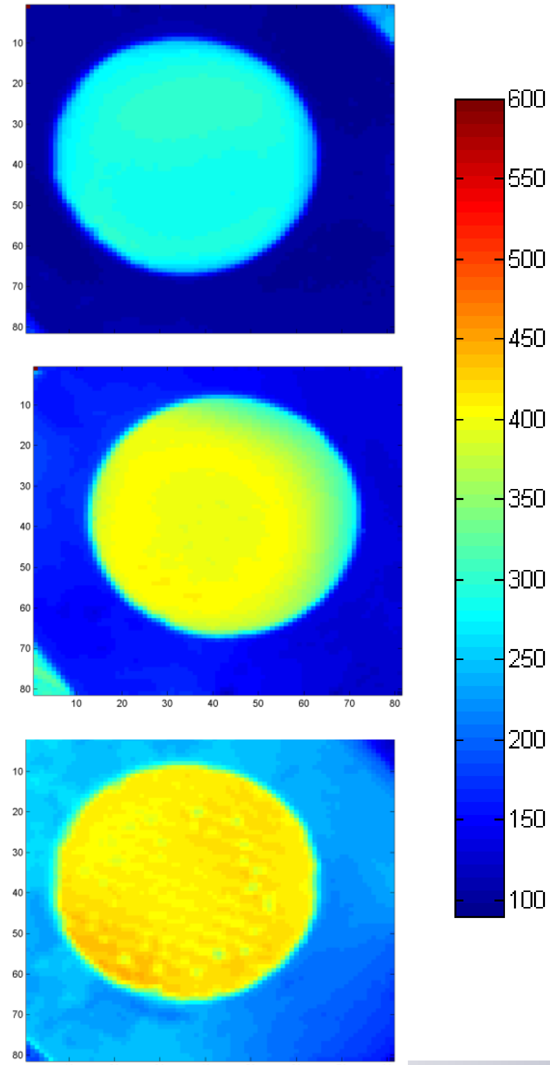
After exposure observations

Température Face arrière (°C)

30s

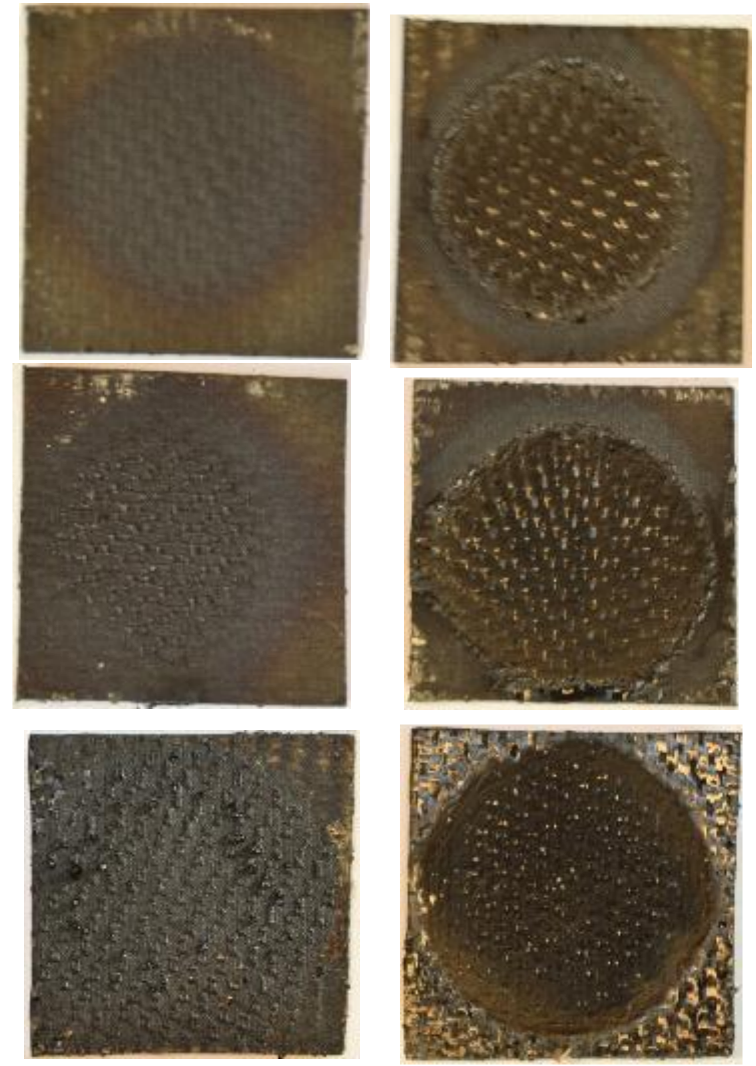
60s

90s



Face arrière

Face flamme



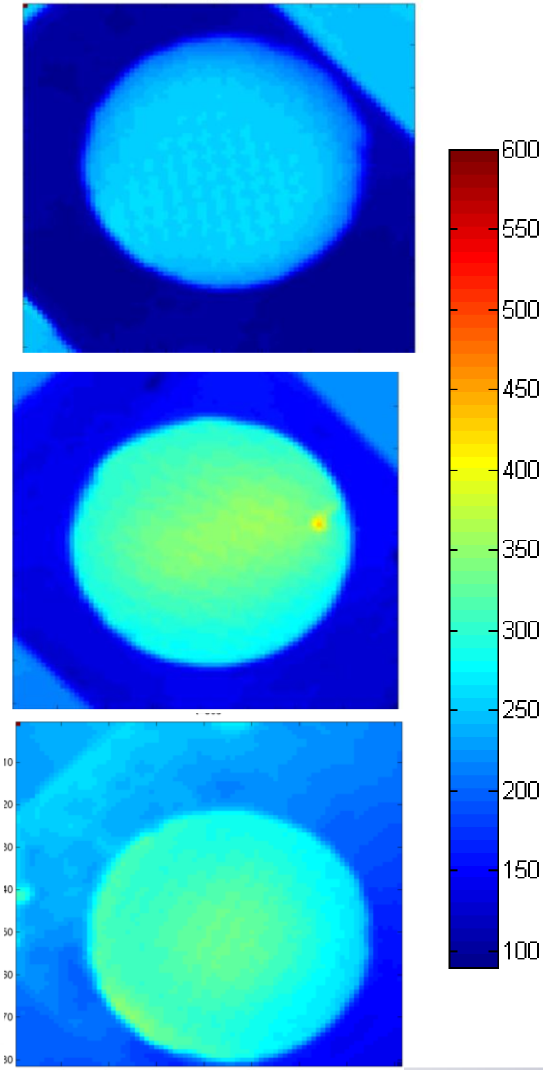
After exposure observations

Température Face arrière (°C)

30s

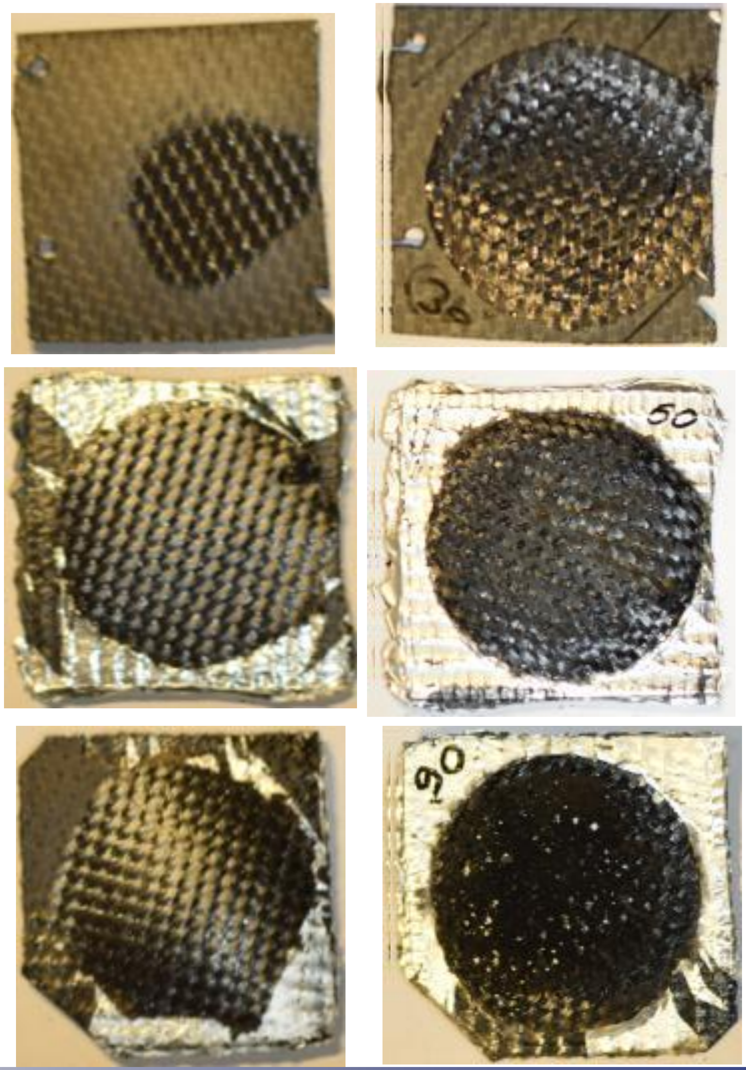
60s

90s

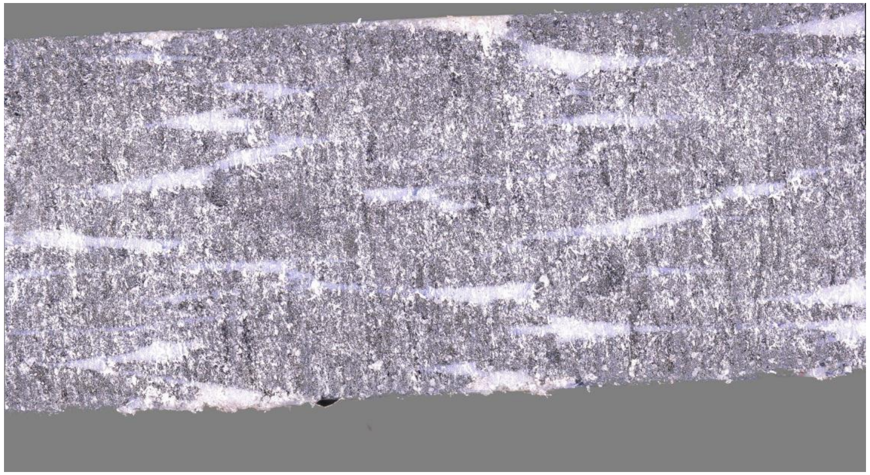


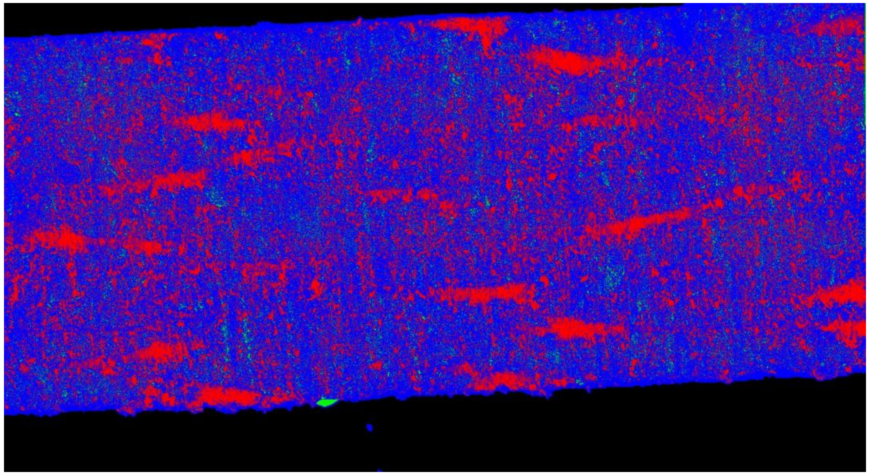
Face arrière

Face flamme



Numeric image analysis : C/PPS





Matrice 37 %

Porosité 8%

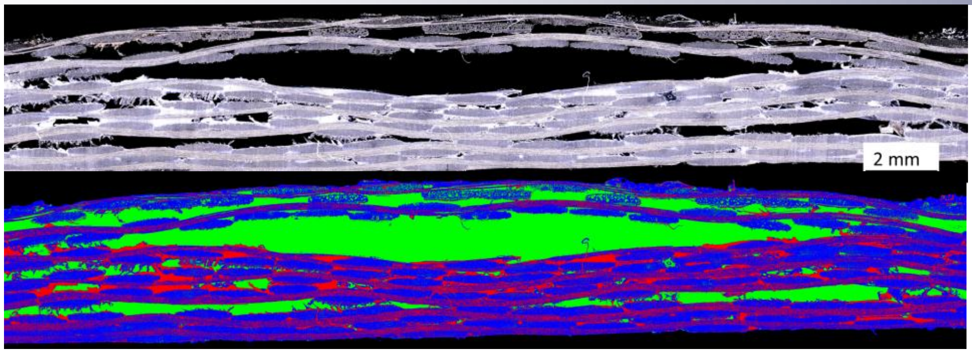
Fibre 55%

Carbone/PPS vierge

68%$_{vol}$ Fibre

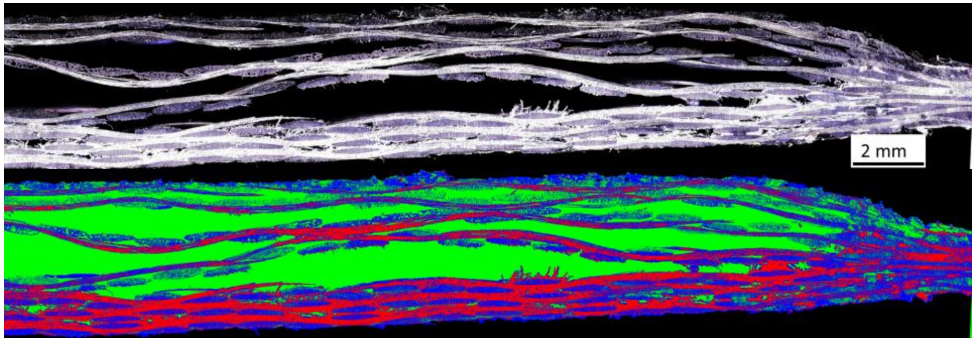
After exposure observations : C/PPS

30s

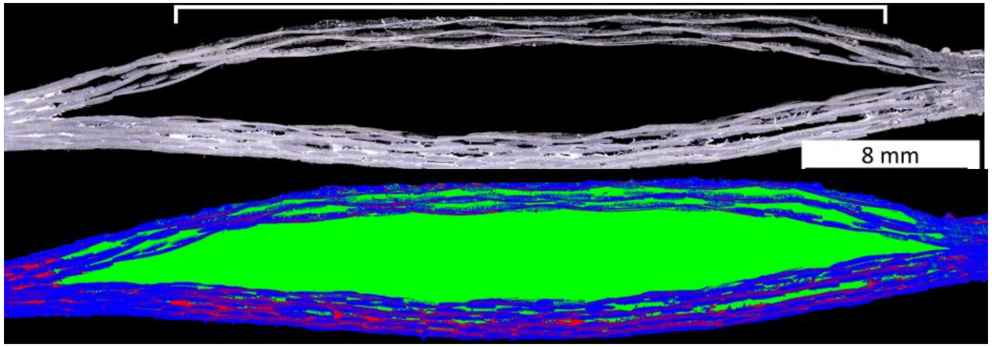


	30 s	60 s	90 s
Voids%	32	56	77
Matrix%	23	24	7
Fibre%	45	25	16

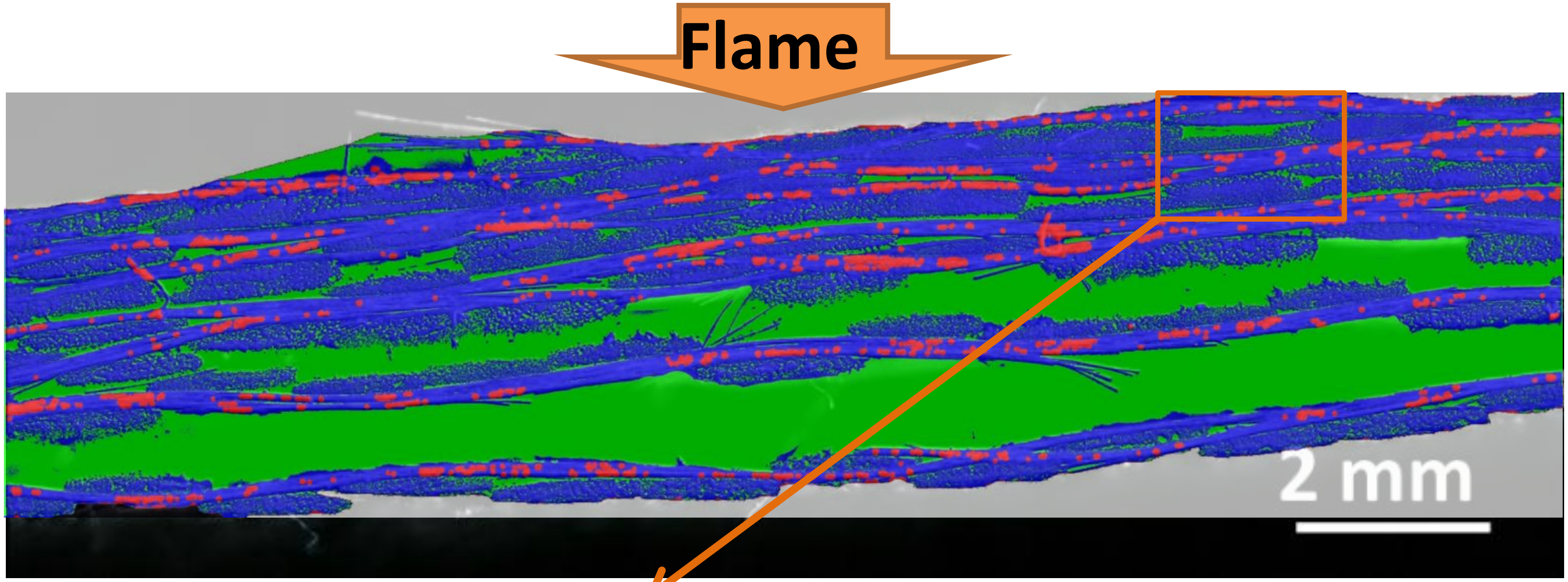
60s

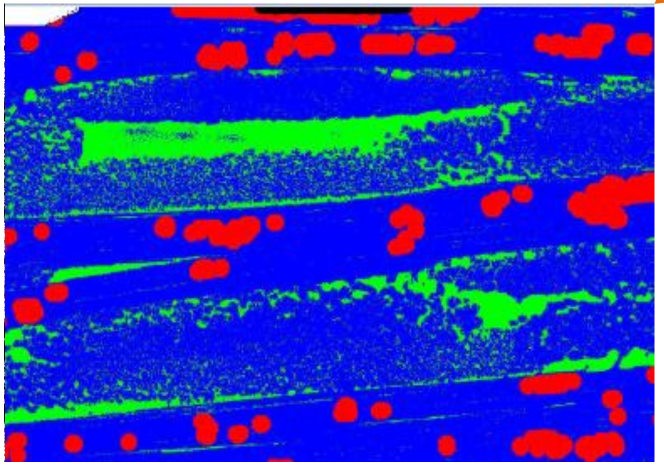


90s



After exposure observations
C/Epoxy





	C/Epoxy
Voids	40 %
Matrix	7 %
Fibre	53 %

Conclusion

1. The propane burner used for this study is able :
   - to provide easily the fire degradation of a small sample under high thermal flux, up to 200kW/m2.
   - to provide accurate values of mass and temperature during the fire degradation of a small sample.

2. The automated image processing allows a quantitative analyse of the sample degradation.

   - The use of a propane/air flame at stoichiometry highlights the impact of a non-oxidizing flame on the fibre degradation at high heat flux.
   - The image analysis enables the characterisation of different degradation processes inside the Epoxy- and PPS-based samples.

   (voids building, major delamination, matrix degradation or melting)

Development and Objectives

1. Study of the composites reaction to fire under high flux (200 kW/m²)

2. Study of the simultaneous mechanical and thermal stress on composite samples.

Merci pour votre attention

Questions ?