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David Philippe, Benoît Vieille, Fabrice Barbe

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D. Philippe*, B. Vieille, and F. Barbe
Normandie Univ, INSA Rouen, UNIROUEN, CNRS, GPM, 76000 Rouen, France
* Corresponding author (david.philippe@insa-rouen.fr)

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During their lifetime, aeronautical composite structural parts may be subjected to extreme thermal exposures, such as an impinging flame during a fire scenario. As the temperature rises (up to 1150°C according to Federal Aviation Administration regulations [1]), the thermomechanical properties of the laminates are severely degraded which may cause the structural failure of the aircraft parts. The coupling between the thermal transfers and the mechanical response therefore needs to be investigated to be fully understood to avoid drastic accidents [2,3].

The aim of this experimental and numerical study is to further understand the behavior of quasi-isotropic (QI) and ±45° laminates of carbon reinforced thermoplastic (polyphenylene sulfide or PPS) at temperatures exceeding the onset of thermal decomposition (temperatures above 450°C). During the thermal decomposition process, the polymer matrix progressively undergoes a pyrolysis reaction transforming into pyrolysis gases and carbon residue [4]. As a result, gas-filled porosities germinate and grow within the laminates, inducing internal pressure in various locations leading to a swelling of the material. The objective is to experimentally characterize the porosity formation phenomena to propose a predictive numerical model accounting for the influence of a temperature increase on thermal decomposition of the matrix and reflecting the degradation of the laminates [5].

To reach that purpose, the thermal decomposition state was quantified in terms of porosity volume fraction η_p within the laminates after thermal exposure (computed according to volume increase and mass loss) while the qualitative overview of the phenomena was performed using optical microscopy and X-Ray tomography (Fig. 1).

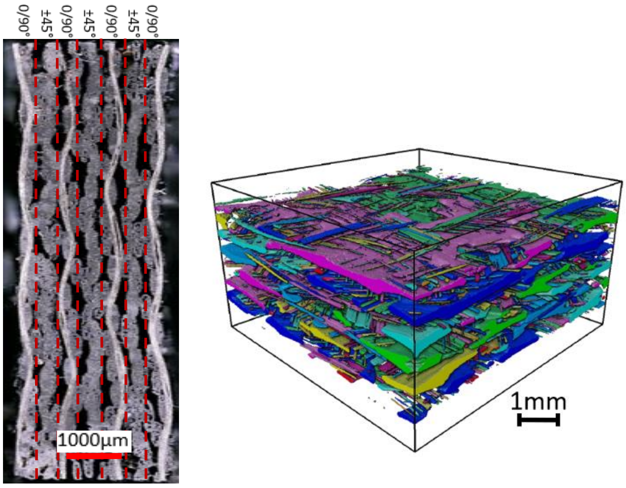
η_p and thickness variations were experimentally determined for various times / temperatures using a homogeneous temperature in a furnace under isothermal conditions. Temperatures were limited to 600°C since the decomposition was advanced too much
to perform measurements beyond.

The proposed 3D Finite Element (FE) numerical model is able to reproduce the porosity volume fraction within the composite material. For computation time considerations, the model size was limited to an elementary volume (Fig. 2). At to the mesoscopic scale are explicitly represented the matrix and the fiber bundles, the local structural changes within the matrix are captured by transforming matrix elements into porosity ones and by applying an internal pressure to reproduce the swelling.

This model is based on experimental observations of thermally-degraded laminates which have shown a randomness in the localization of nucleating porosities, which has led to describing the progressive nucleation process using a probabilistic law: each matrix element has a probability to turn into a porosity according to the thermal exposure time and its temperature.

The model parameter identification in homogeneous temperature conditions led to predictive simulations of the fire scenario by introducing a heat flux applied on one of its sides and heat exchange boundary conditions (convection, radiation) (Fig. 3). The numerical results will be compared to experimental ones obtained with a kerosene burner to assess the predictive capability of the model.

This model will be further developed to estimate the impact of property degradation and structural changes through thermal decomposition on the thermo-mechanical response of the composite laminates.



(a) (b)

Fig. 1. Observations of QI laminates thermally-decomposed at 530°C for 7min (a) optical microscope (b) X-Ray tomography

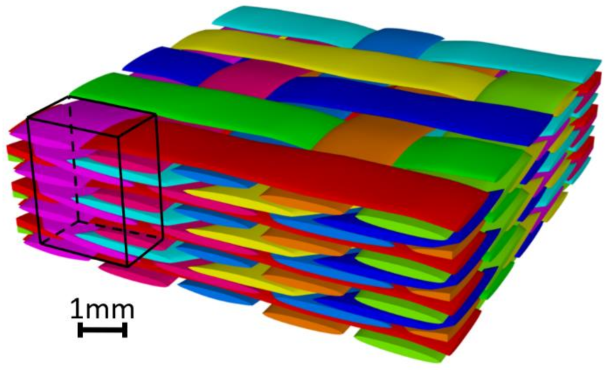


Fig. 2. QI RVE model and selected 1/28th subdomain

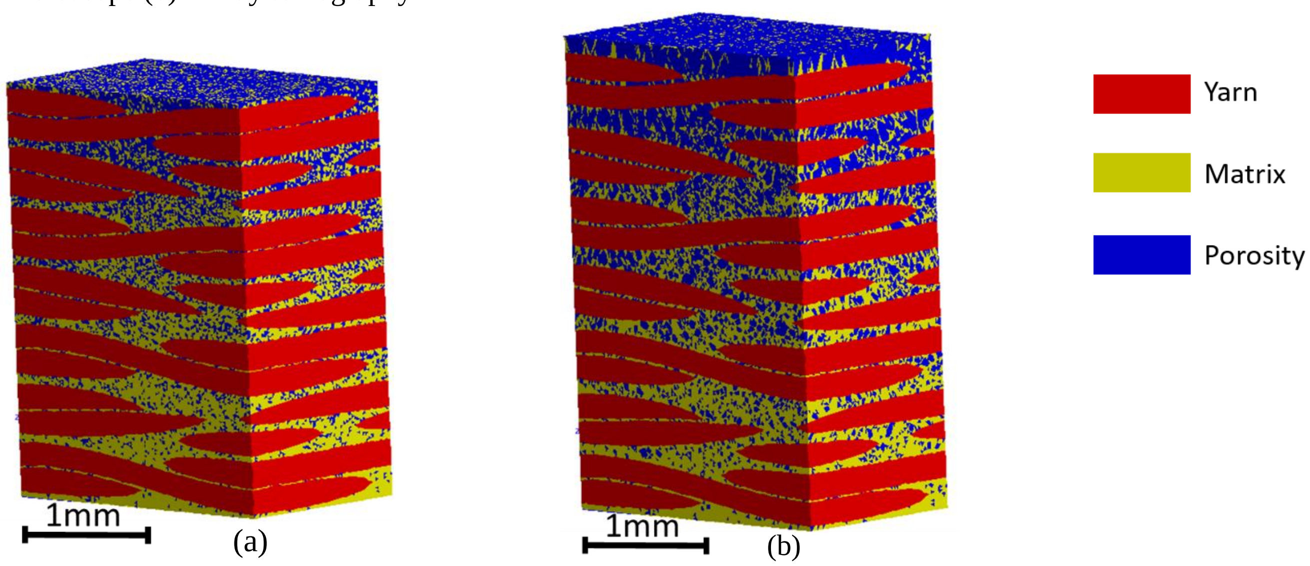


Fig. 3. Thermal decomposition modelling of QI C/PPS laminates subjected to a 120 kW/m² heat flux for 90s (a) without swelling (b) with swelling

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