4D PRINTING OF TEMPERATURE DRIVEN SMART COMPOSITE MATERIALS FOR SPACE APPLICATION

Roxane TOUMI[1], Mickael CASTRO[1], Justin DIRRENBERGER[2], Fabrizio SCARPA[3], Ugo LAFONT[4], Raffaele DELIA[5] and Antoine LE DUIGOU[1]

1 :IRDL UMR CNRS 6027, Université de Bretagne Sud, Centre de recherche C Huygens, 56100 Lorient, France (roxane.toumi@univ-ubs.fr)

2 : Laboratoire PIMM, Arts et Métiers-ParisTech, CNAM, CNRS, 151 bd de l'Hôpital, 75013 Paris, France

3 : Aerospace Engineering, Bristol Composites Institute (ACCIS), School of Civil, Aerospace and Mechanical Engineering, University of Bristol, BS8 1TR Bristol, UK

4 : European Space Research and Technology Centre, European Space Agency, Keplerlaan 1, PO Box 299, 2200 AG Noordwijk, The Netherlands

5 : IRT Saint-Exupéry, 3 rue Tarfaya – CS34436 – 31405 Toulouse Cedex 4, France

Abstract

Long-term human exploration of the Moon and Mars is a major project in today's space exploration that requires to rethink infrastructure design with in situ construction and reliable structures. Moreover, these structures must be able to adapt autonomously to their environment, as do certain biological structures (pine, sunflower…), leading to more sustainable bases on the Moon or on Mars. This would reduce maintenance issues while optimizing infrastructure performance.[1]
4D printing is a new technology based on additive manufacturing applied to certain materials, which present spatio-temporal actuation, pre-programmed by their multi-scale architecture. This is a major tool to meet the ambitions of space exploration.[2], [3]

This presentation will focus on the 4D printing fabrication of a high performance composite material for space application.

The material used is based on continuous carbon fibers embedded in a polyamide (PA) matrix called cCF/PA6-I. This is a first step before considering the use of in-situ resources and possibly regolith-based fibers. The printing parameters have been set to ensure high quality and a reduced porosity, as well as enhanced mechanical properties compared to other 3D printed structures made from continuous carbon fibers composites.[4]–[6]

The material has been tested mechanically in several directions (0, 90 and ±45°) at temperatures from -150 to + 150°C representative of the lunar environment.[7] Its properties are temperature dependent, especially transverse and shear properties, which are strongly affected due in particular to the sensitivity of the polymer matrix to temperature as it can be seen in the fractured surfaces in Figure 1.

Large thermal fluctuations also result in thermal expansion that can be used as a trigger for actuation/morphing depending on a dedicated architecture and anisotropy control. To use efficiently this important parameter, bi-layers are made from cCF/PA6-I and Onyx a composite made of chopped carbon fibers embedded in a polyamide matrix with different printing patterns. Both materials are black leading to a great absorptivity of direct solar radiations on the Moon surface. They are tested to analyse their shape change under heating effect with the future goal of being used as building blocks for self-shaping mechanical metamaterials.

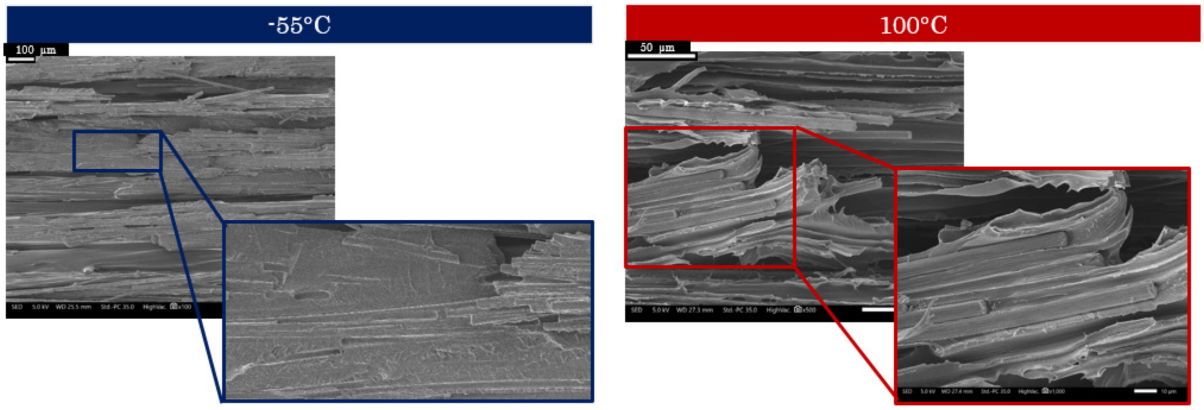

Figure 1. Comparison between fractured surfaces of a 90 degrees oriented specimens. On the left, at -55°C, a fragile fracture of the matrix is visible whereas on the right, at 100°C a ductile fracture of the matrix can be seen.

References

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