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INITIAL CHARACTERIZATION OF MULTIPLE SHAPE-MEMORY ANYCUBIC RESIN

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1. Introduction

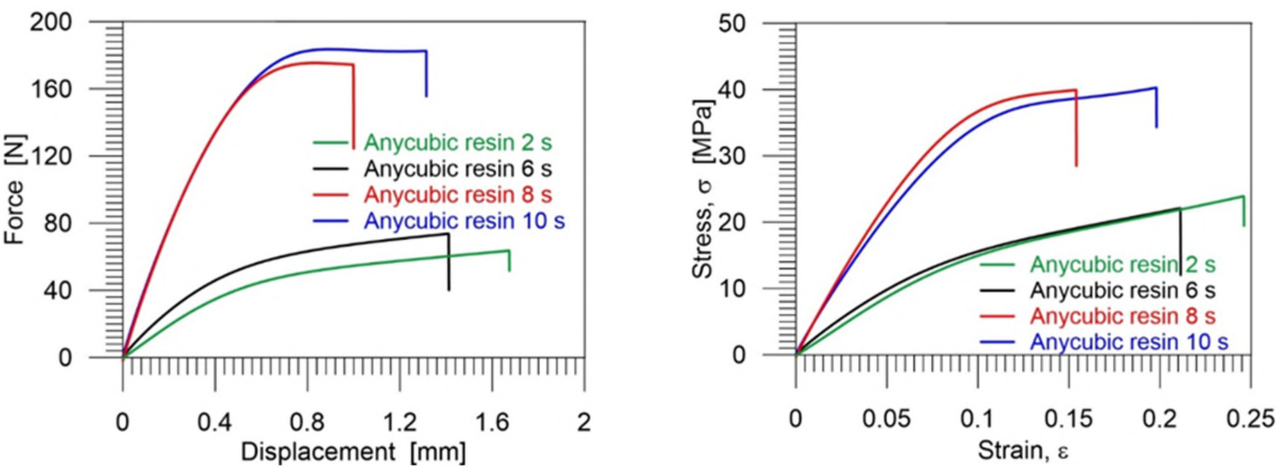
The Shape Memory Polymers (SMP) are multifunctional materials that can change their shape under external stimuli, usually temperature [1-2]. The temperature is usually glass transition temperature T_g for Polyurethane Shape Memory Polymers (PU-SMP) [3, 4] or shape memory epoxy (SMEp) [5], characterised by a relatively high strength and beneficial shape memory properties which enables various applications in the medical or industrial instruments and daily life. Particularly interesting is a new generation of multiple Shape Memory Epoxy (SMEp) that demonstrate the ability to memorize more than two shapes. The property significantly broadens the functionality of SMPs making them attractive for applications from robotics to biomedicine. The multiple shape memory effect (SME) can be achieved through additive manufacturing (AM), particularly 4D printing.

2. Materials and methods

The research concerns SMP specimens made from anycubic resin, a mix of some epoxies and acrylates, which were printed using Digital Light Processing (DLP) technique. Various times of polarization, i.e. 2 s, 6 s, 8 s and 10 s per layer, were used.

3. Results and concluding remarks

The comparison of the mechanical behavior of the specimens obtained by the 4D printing with various exposure times per layer during the loading till rupture with a strain rate of 10^{-2} s^{-1} at room temperature is presented as force-displacement and stress-strain curves in Fig. 1a and Fig. 1b, respectively.



(a) (b)

Fig. 1. Comparison of (a) force-displacement and (b) stress-strain curves for anycubic resin specimens

In addition, the shape memory properties of the specimens were investigated in the thermomechanical loading program performed in the thermal chamber of the Instron testing machine. At the initial stage, the specimen was heated to $T_h = T_g + 20°C$ at 12 °C/min. After that, tension loading was applied with a strain rate of 10^{-2} s^{-1} at $T_g + 20°C$ until a maximum programmed strain was reached. Next, the specimen was cooled to low temperature T_l , which corresponded to either room temperature (24 C°) or T_g - 20°C depending on the specimen, while maintaining the maximum strain (ε_m) to fix its temporary shape. Then the specimen was unloaded to zero-force at T_l with a strain rate of 10^{-2} s^{-1}, demonstrating the shape fixity. Finally, the specimen was reheated from T_l to T_h at a heating rate of 12 °C/min in no-load conditions, leading to the shape recovery.

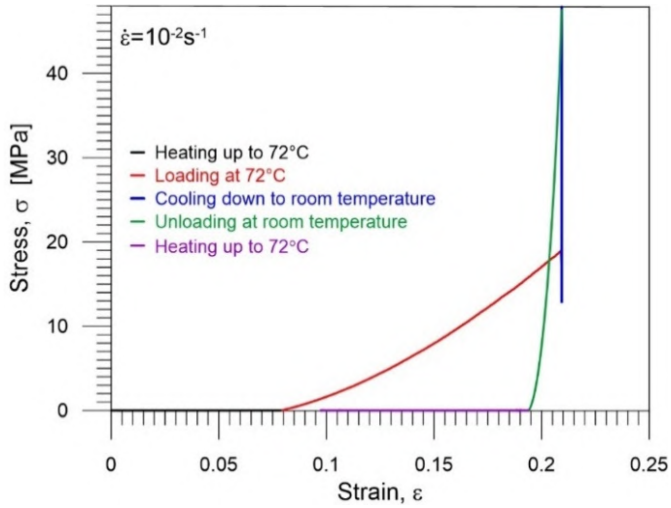


Fig. 2. Stress vs. strain curve obtained during thermomechanical loading program [6] of the specimen with 10 s per layer; particular colors of curves mark subsequent stages of the program.

The example of the stress vs. strain curve obtained during the thermomechanical loading program [6] of the specimen with the exposure time of 10 s per layer is shown in Fig. 2. The shape fixity and shape recovery parameters, obtained for anycubic specimens with different exposure times per layer, demonstrated high sensitivity of the DLP parameters used, on the SMEp application parameters.

4. Acknowledgements

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