

INFLUENCE OF Z-PIN'S CURING DEGREE ON PROPERTIES OF LAMINATES AND ITS MECHANISM

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1. Introduction

Comparing with other 3-D reinforced techniques, Z-pinning makes the interlaminar properties of laminates strong especially, especially for the prepregs. Many works have been done about properties with mechanical analysis, but few concern the materials and its structure. In this paper, we will investigate some pivotal factors of Z-pins that affect the interlaminar properties of Z-pins reinforced laminates.

2. Experimental work

Z-pins of carbon fiber/epoxy with different curing degrees were got by pultrusion process as shown in Fig.1. Carbon fibers were impregnated in the epoxy, with controlling the pultrusion speed, die temperature and oven temperature of post-curing (Tab.1).

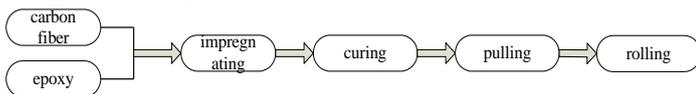


Fig.1 Pultrusion process of Z-pins

Tab.1 Parameters of pultrusion process

Drag speed, mm/min	350-400
Die temp., °C	99
Curing tunnel temp., °C	94-98
Diameter, mm	0.5
Fiber volume fraction, %	63

The curing degrees of Z-pins were measured with differential scanning calorimetry (DSC) and

calculated by equation 1 and given in Tab.1

$$\alpha = \frac{H(t)}{H_u} \quad (1)$$

The curing degrees of Z-pins with different pultrusion parameters were obtained and shown in Tab.2

Tab.2 Curing degrees of Z-pins with different pultrusion parameters

No.	Drag speed, pps	Die temp., °C	Curing tunnel temp., °C	Curing degree, %
1	450	99	96	42.09
2	400	99	98	53.97
3	350	99	97	69.94

Nine Z-pins were embedded into the prepreg laminates with the dimension of 40mm × 20mm × 5mm with a polytetrafluoroethylene insulated membrane in the middle. The test set up for pullout of the samples can finely describe the interlaminar properties of Z-pins reinforced laminates[1]. Fig.2 shows the experimental fixture of the Z-pin pullout test.

3. Experimental result and analyze

The pullout test results showed that the interlaminar strength increased when the curing degree of Z-pins went down. The samples with the all-cured Z-pins, the average pullout force is 257N, and the average pullout force with the partly-cured Z-pins can reach to 412N, having an increase of 60%. From average pullout force with the

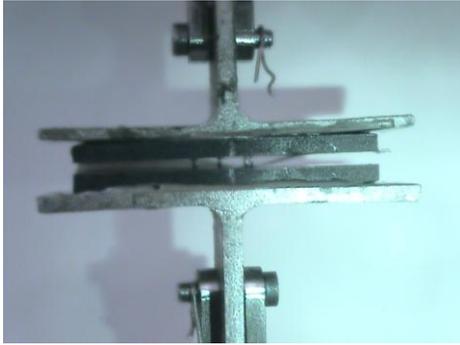


Fig.2 Experimental fixture of Z-pin pullout test

partly-cured Z-pins can reach to 412N, having an increase of 60%. From the Fig. 2, we can also observe that the Z-pins were pulled out of the laminates. Analyze the mechanics of these phenomena, the resistance of the delamination is divided into two parts: the elastic deformation of the interfaces between Z-pins and laminates and the interfacial friction between Z-pins and laminates. Fig.3 shows the Load-displacement curves of laminates reinforced by Z-pins of different cure degree.

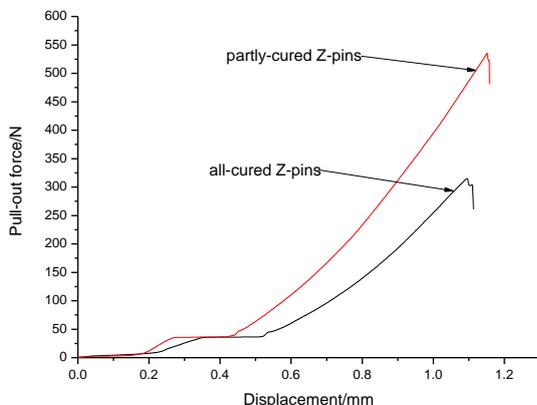


Fig. 3 Load-displacement curves of laminates reinforced by Z-pins of different cure degree

Compared with the all-cured Z-pins, partly-cured Z-pins have more co-cured with laminates, and the interfacial bonding is firmer than the former. When the laminates are delaminated under the exogenic action, laminates with partly-cured Z-pins can resist

more exogenic. Fig. 4 illustrate the patterns of the pulled out Z-pins

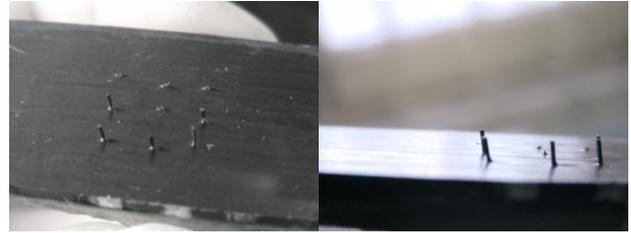


Fig.4 Profile and patterns of the pulled out Z-pins

After the interfacial debonding occurred and propagated completely, the new interfaces between Z-pins and laminates of the laminates reinforced with partly-cured Z-pins are rougher than the former. So in the process, the Z-pins are pulled out of the laminates, the later need the larger exogenic. The macroscopical phenomena are the average pullout force of the laminates reinforced with partly-cured Z-pins is larger than that with all-cured Z-pins.

4. Conclusions

Composite Z-pins with different curing degrees were prepared by pultrusion process and the pullout test were carried out. Compared with the all-cured Z-pins, partly-cured Z-pins are more effective on improving the interlaminar properties of laminates than those of fully cured Z-pins. This results suggest a new approach for traditional methods of Z-pin interlaminar reinforcement and further study will be done to find out the optimal curing degree of Z-pin for the best reinforcement effect.

References

- [1] S.C. Dai, W.Yan, H.Y. Liu, Y.W. Mai "Experimental study on z-pin bridging law by pullout test". *Composites Science and Technology*, Vol.64, pp 2451-2457, 2004.