Supporting Information

Composite of knitted fabric and soft matrix. I. crack growth in the course direction

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In pure shear tests, boundary conditions are established to ensure that the material experiences only shear stress. Typically, the undeformed sample is a long, thin strip with an initial width L_0 and height H. The condition $L_0 \gg$ H and $c \gg H$ allows for a pure shear state[1] (Fig. S1). Generally, the bottom of the sample is fixed during testing, so the first boundary condition is:

$$u_1(y = 0) = 0 \tag{s1}$$

A vertical displacement Δ is imposed on the top of the strip, so the second boundary condition is:

$$u_2(y = H) = \Delta \tag{s2}$$

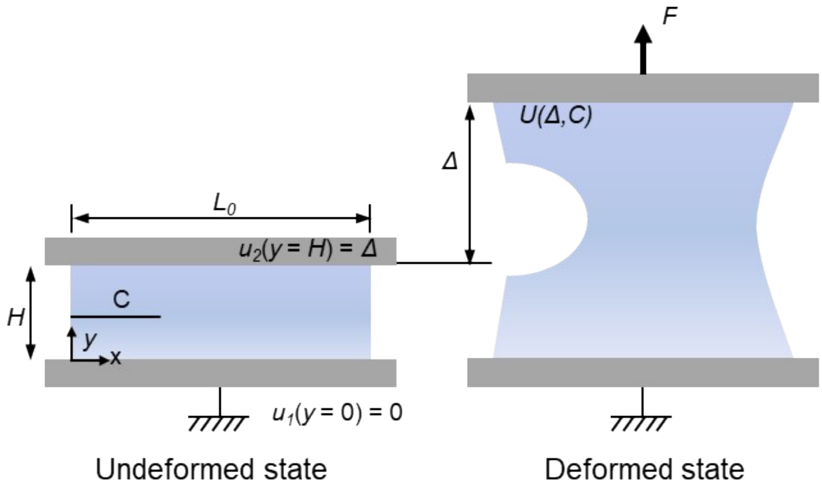

Fig. S1 The schematic of boundary condition of the pure shear sample.

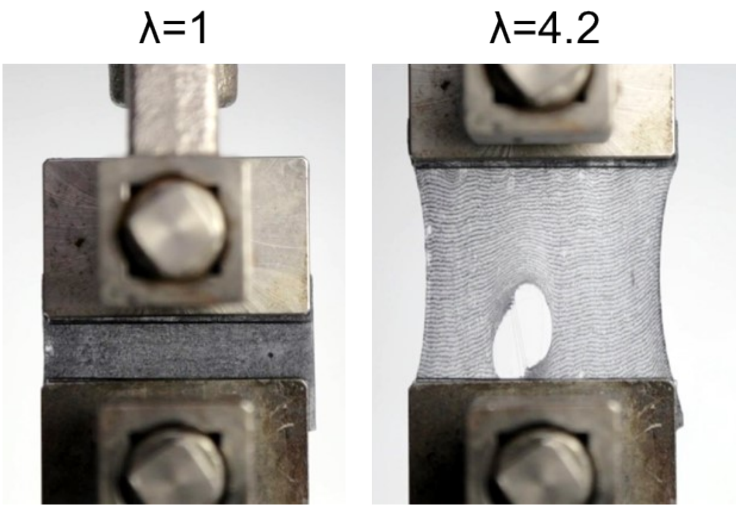

Fig. S2 A knit-PCU composite stretch to the ultimate stretch and appears a large hole.

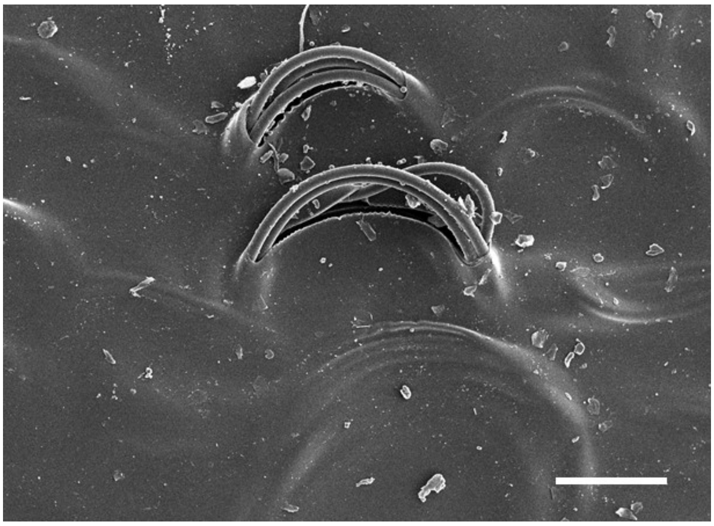

Fig. S3 The matrix damage of the knit-PCU composite observed in a scanning electron microscope. Scale bar is 200 μm.

To understand why the crack propagates in this unique way for the composite of knitted fabric and soft matrix, a qualitative model is presented in Fig. S4. When the sample is stretched, the yarn is pulled out from the matrix, and forms a bridging zone. The bridging yarn slips on the knit loops near the crack tip. The pullout process of the yarn is modeled as a rope passing through a capstan (Fig. S4a), with a friction coefficient of μ. When the yarn bypasses a loop, it goes upward from one side and downward to the other side. The contact angle of the rope and the capstan is denoted as θ. The tension on the yarn can be calculated by the Euler-Eytelwein equation[2]

$$T_1 = T_o\, e^{\mu\theta} \qquad \text{(s3)}$$

where T_1 is the tension in the right part of the yarn, and T_o is the tension in the left part. In the bridging zone, the yarn passes through multiple knit loops (Fig. S3b). We assume that the free end of the yarn offers a small tension of T_o. When the yarn bypasses the first loop, the tension on the yarn will increase to T_1. After bypassing n loops, the tension in the yarn is calculated as:

$$T_n = T_{(n-1)}\, e^{\mu\theta} = T_o\, e^{n\mu\theta} \qquad \text{(s4)}$$

Eq. s2 shows that the tension in the yarn increases with the number of loops that the bridging yarn bypasses. The highest tension in the bridging zone appears on the nearest segment of the yarn to the crack tip. When T_n equals to the strength of the yarn, the yarn breaks at the crack tip.

Finite element analysis is applied to illustrate the fracture process of the composite of knitted fabric and soft matrix (Fig. S4c). The yarn bridges crack surfaces, forming a bridging zone. In order to calculate the tension distribution in the bridging zone, we mark the end of the bridging yarn as i = 0. When the yarn bypasses a knit loop, the segment of the yarn is marked as i = 1. The tension in the segment increases with the segment number (Fig. S4d). As the stretch increases, the tension in the bridging yarn gradually reaches the strength of the yarn, and the yarn breaks at one location near the crack tip. One part of the broken yarn hangs on the crack surface, and another part of the yarn forms a new bridging zone to resist the crack growth.

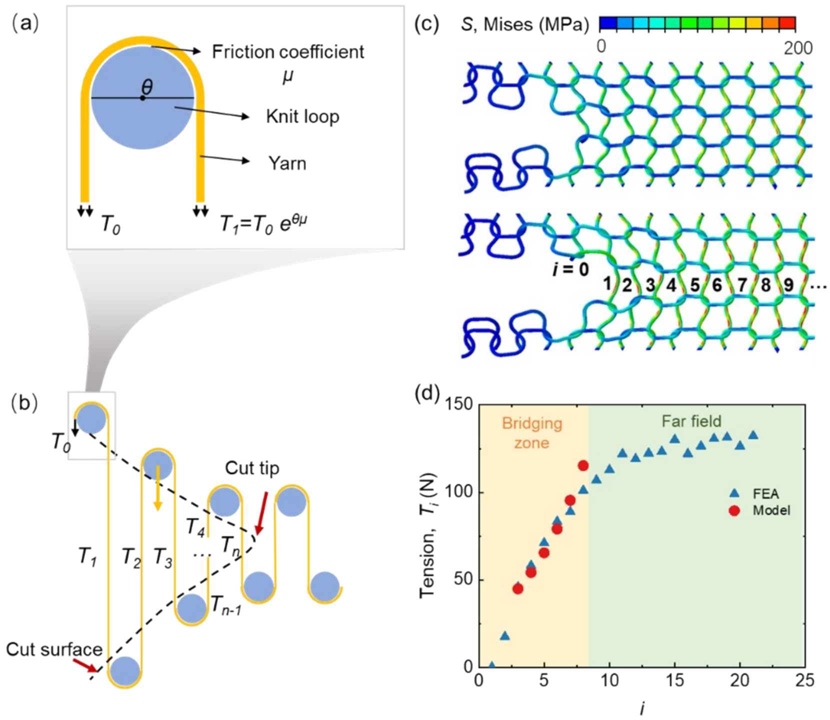

Fig. S4 Schematic and finite element analysis of the bridging zone in the composite. (a) A yarn slips on a knit loop with friction. (b) The distribution of tension in the bridging zone. (c) Finite element analysis for the fracture process of the composite. (d) The tension in the yarn vs. the loop-number i.

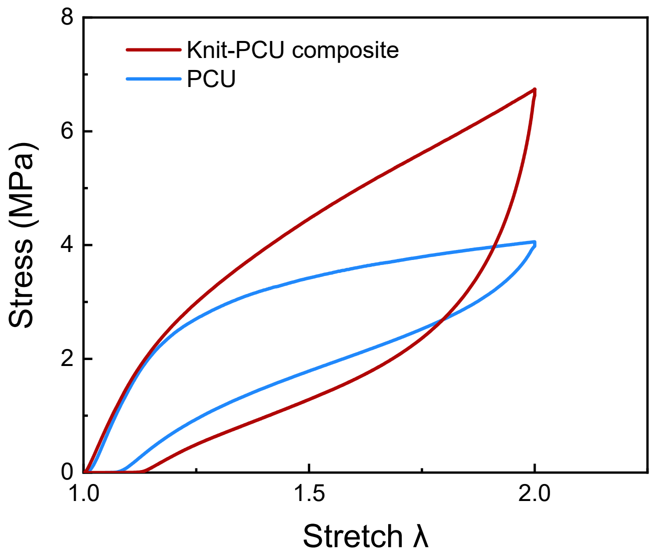

Fig. S5 The stress-stretch curve of knit-PCU composite and neat PCU under a loading-unloading cycle.

Reference:

1 R. Long and C. Y. Hui, *Soft Matter*, 2016, 12, 8069-8086.

2 P. Grandgeorge, T. G. Sano and P. M. Reis, Journal of the Mechanics and Physics of *Solids*, 2022, 164.