Experimental study of biaxial behavior of PVB

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Polyvinyl butyral (PVB) is a kind of high molecular polymer and it is widely used as the interlayer of laminated glazing for its good transparency, adhesion, toughness and bending properties. PVB coheres two or more pieces of glass panels together to enhance the stiffness of the whole laminated glazing as well as bond glass fragments when the glass is broken. Some researches have been conducted on the mechanical properties of PVB. Iwasaki, Morison and Hooper did the uniaxial tensile experiments at low strain rate and high strain rate. It was found that PVB can be considered as a nonlinear visco-elastic material at low strain rate while elasto-plastic material at high strain rate. Rong Wenjie and Wu Xiqiang obtained stress-strain curves of PVB by quasi-static tension tests and high speed tension tests respectively at different temperatures from -30℃ to 40℃, from which the mechanical properties of PVB can be represented by bilinear model at low temperature and hyper-elastic model at high temperature. The results of previous researches show that PVB has the character of low strength and large deformation, its mechanical properties are sensitive to strain rate and temperature and different material models should be proposed according to the temperature and strain rate.

Previous researches on the mechanical properties of PVB mainly adopted the uniaxial tensile test approach giving rise to a state of stress largely different from that in the PVB in laminated glasses. The stress state of PVB in laminated glazing under working condition is complex with multi-directional loading on it. A biaxial tensile test approach can simulate the stress state more accurately compared to the uniaxial tensile test approach. Thus it is more meaningful to investigate the mechanical properties of PVB using a biaxial tensile test approach.

In this paper, a cruciform specimen of PVB is specially designed for the biaxial tensile test and the dimension is optimized based on numerical parametric study. The specimen (Fig.1) is in the shape of two orthogonal arms with seven slots on each arm and holes at the end of each slot. Slots on the arm can effectively achieve the uniform distribution of stress in the center of the specimen. The hole at the end of the slot can effectively reduce stress concentration. These cruciform specimens are laser-cut to ensure the quality.

These cruciform specimens of PVB are tested with the biaxial tensile tester in the mechanical testing center of Shanghai University at the temperature of15℃ and low strain rate (Fig.2). Displacement loading scheme is adopted and five ratios between x-axis and y-axis displacements are selected, which are 1:1, 2:1, 3:1, 4:1and 1:0 respectively, and the ratio of 1:0 means that the end of y-axis was clamped but did not move. To obtain the stress and strain state at the center of the cruciform specimen of PVB, the stress is obtained from the load via force sensor installed at the end of the arm and the deformation is deduced from the change of a grid marked on the specimen surface as recorded by a CCD camera.

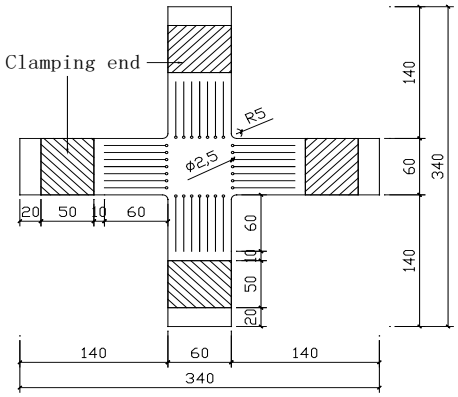
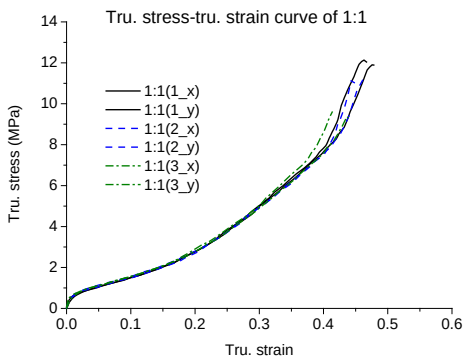


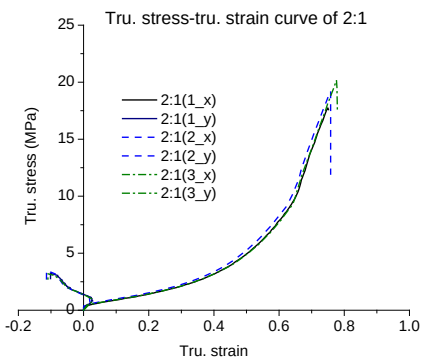
Fig.1 The cruciform specimen

Fig.2 Biaxial tensile test of PVB

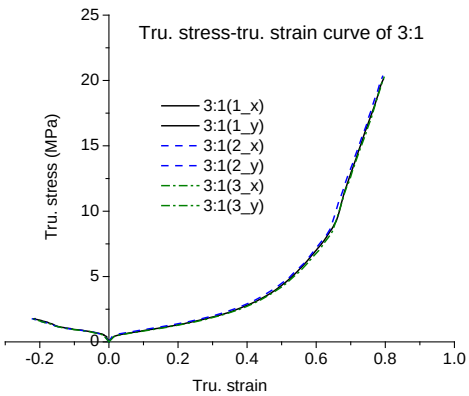
The results of the biaxial tensile test indicate that the behavior of PVB is highly nonlinear under biaxial tensile loading. The stress-strain curve shows the property of a hyper-elastic model. The data show that when the displacement ratio is 1:1, both axes at the center of PVB have similar stress-strain curve and undergo positive strain. Whereas, when the ratio is 2:1 there is a large difference between x-axis and y-axis, the y-axis undergoes a process from positive to negative strain and the x-axis keeps the positive strain. For displacement ratios of 3:1, 4:1, the y-axis undergoes the negative strain while the x-axis keeps the positive strain. Typical stress-strain curves are shown in Fig.3.



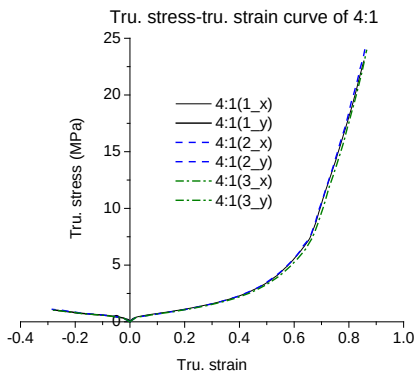
(a) 1:1



(b) 2:1



(c) 3:1



(d) 4:1

Fig.3 True stress-strain curve