Numerical models of the delamination behaviors in the 2G HTS tape under transverse tension and peel

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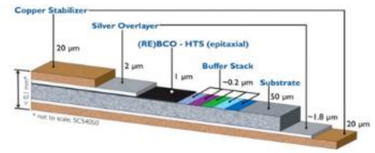
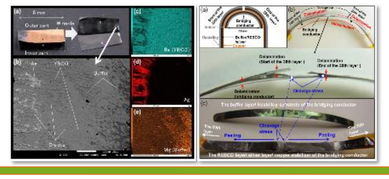
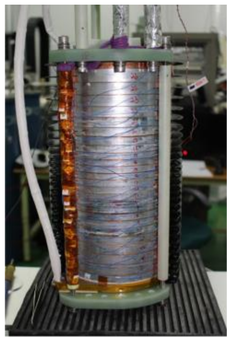
Introduction

1. 2G HTS tape: has a multi-layers composited construction.
2. Application: magnets and cables, etc.
3. Delamination: with the fragile feature of the superconducting layer, the 2G HTS tape will separate physically under the tensile or shear stress, generated due to fabrication, Lorentz force and thermal mismatch, etc. The delamination will result in serious degradation of the critical current.

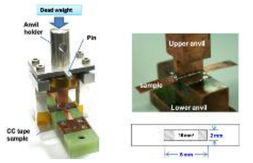


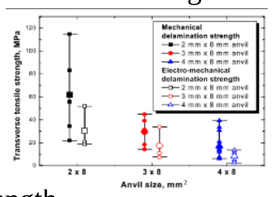




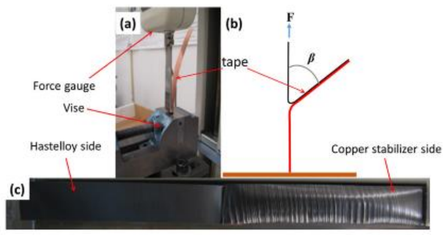
Research status

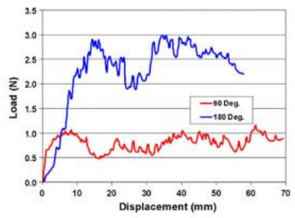
1. Anvil test for the transverse tensile strength





2. Peel test for the peel strength

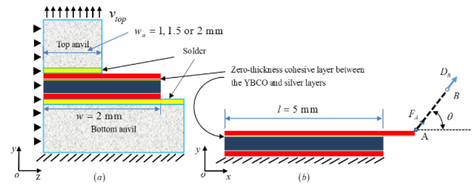




Motivation

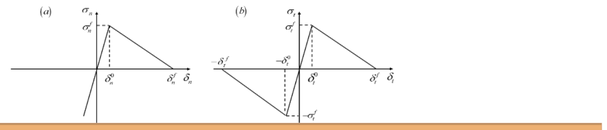
1. Is the transverse tensile strength from the anvil test equal to the real strength?
2. Why is the peel strength at 180° larger than that at 90°?
3. Which factors affect the peel strength?

Numerical models



Anvil model (a) and peel model (b)

The mixed-mode traction-separation law

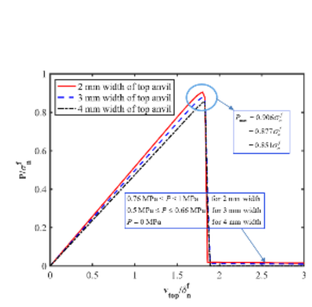


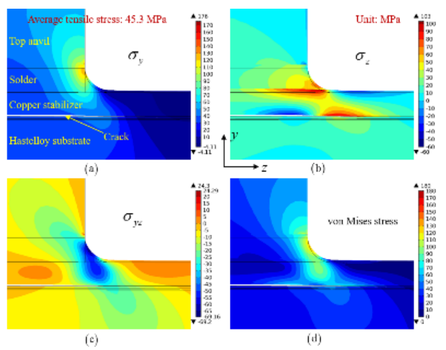
The law can be described by the onset relative displacement, the final relative displacement and the fracture toughness .

$$\delta_m^0=\begin{cases}\delta_n^0\delta_t^0\sqrt{\dfrac{1+\beta^2}{\left(\delta_t^0\right)^2+\left(\beta\delta_n^0\right)^2}}, & if\ \delta_n>0,\\ \delta_t^0, & if\ \delta_n\le 0,\end{cases}\qquad \delta_m^f=\begin{cases}\dfrac{2G_{mc}}{K_p\delta_m^0}, & if\ \delta_n>0,\\ \sqrt{2}\delta_t^f, & if\ \delta_n\le 0,\end{cases}$$

$$G_{mc}=G_{nc}+\left(G_{tc}-G_{nc}\right)\left(\frac{\beta^2}{1+\beta^2}\right)^{\eta},\qquad \begin{bmatrix}\sigma_n\\ \sigma_t\end{bmatrix}=\mathbf{C}\begin{bmatrix}\delta_n\\ \delta_t\end{bmatrix}.$$

Results for the anvil model



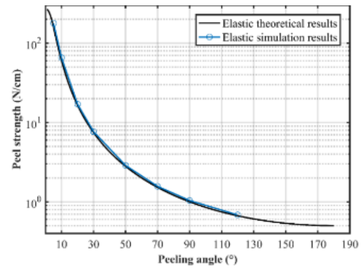


Transverse tensile stress vs. displacement plot

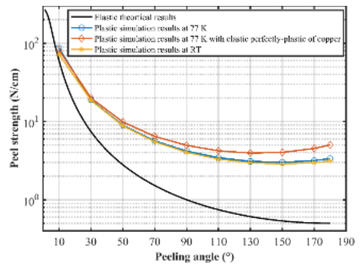
Stresses distribution under maximum tensile stress

◆The maximum average tensile stress, 45.3 MPa, is smaller than the normal tensile strength, 50 MPa.
◆The maximum average tensile stress with a small anvil is larger than that with a large anvil.

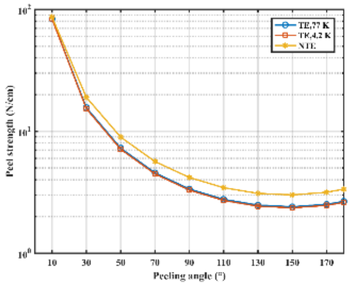
Results for the peel model



Verification of the numerical model

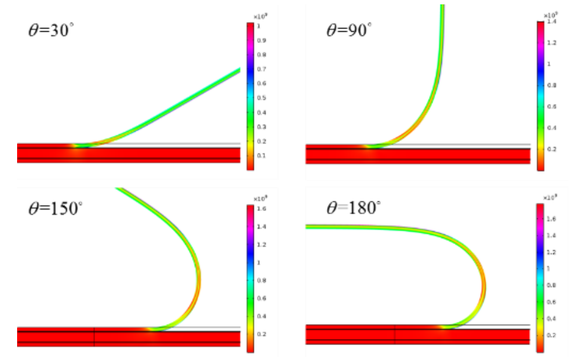


The plastic results compared to the elastic results



The effect of the thermal mismatch

◆The two elastic results coincide mostly.
◆The plastic deformation is a crucial factor for the peel strength, especially at a large peeling angle.
◆With considering the thermal stress, the peel strength is reduced by about 20%.



Von Mises stress distribution

Conclusions

- With considering the mixed-mode traction-separation law , two models are built to investigate the delamination characteristics of the 2G HTS tape.
- The effects of the anvil size on the transverse tensile strength and the stress distribution are analyzed.
- The factors of the peeling angle, the plastic deformation and thermal mismatch, etc. are considered in the peel model.