Novel Through Thickness Reinforcement Development

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Delaminations in Composites

Laminated composites are prone to delamination due to lack of through-thickness reinforcement

Out of plane loading

Geometry of the structure or discontinuities

Impact

[1]

[2]

[3]

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Z-pins Under Mixed-Mode Loading

Transition from pull-out to pin rupture with increasing mode-mixity
Inclined Z-pins

**Aim**
To maximise the bridging effect of TTR pins by changing their orientation in the laminate

- During manufacturing, Z-pins are unintentionally off-set from the vertical z-axis of the laminate on average by 5-15° (using UAZ)

- Z-pins offset *in the nap* show pull-out failure and those loaded *against the nap* show rupture failure under Mode II
0° Vs. 45° T300/BMI Z-pin

Apparent Fracture Toughness

The embedded length of Z-pins increases with insertion angle.

Z-pin embedded length $= \frac{t}{\sin(\phi_{xz})}$

Pull-out energy absorption of 45° Z-pin is higher than 0° Z-pin.
Inclined Z-pins key points

- **Manufacturing:** process is scalable for high production manufacturing

- **Design Considerations:** *Z-pins should be loaded to maximise axial loads.* Increasing the axial loading on Z-pins increases energy absorption

- **Applications:** Lap-joint, T-joints, etc
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