

EFFECTS OF CARBON-FIBRE & COPPER Z-PINS ON THE FAULT CURRENT RESPONSE OF COMPOSITE LAMINATES

Presenter:

Mudan Chen

Co-authors:

Dr. Bing Zhang Mr. Zhaobo Zhang Prof. Giuliano Allegri

Prof. Xibo Yuan

Prof. Stephen R. Hallett

bristol.ac.uk/composites



University of BRISTOL

EPSRC Centre for Doctoral Training in Advanced Composites for Innovation and Science



Engineering and Physical Sciences Research Council



1. Introduction

Demands from the aircraft industry:

- Using electrical power in aircraft to reduce the greenhouse emission;
- Using carbon-fibre reinforced polymer (CFRP) composites to reduce the structural weight.

B787 Dreamliner:

- It uses more electricity, instead of pneumatics, to power airplane systems such as hydraulics, engine start and wing ice protection [1].
- Meanwhile, it has more than 50% of its structure built of CFRP composites, reducing around 20% weight.





[1] http://787updates.newairplane.com/787-Electrical-Systems/787-electrical-system

ICCM23



Engineering and Physical Sciences

earch Council

University of BRISTOL

1. Introduction

Electrical current conduction through the CFRP:

- Localised Joule heating that results in matrix degradation;
- CFRP structure and electrical power system are kept separate via bulky cable harnesses and heavy raceways.
- Integrating the electrical power system with CFRP structures is highly desired.
- But the low electrical fault current inside CFRP is difficult to detect with traditional grounding topology.

Thus, it is crucial to:

- Enhance CFRP's electrical conductivity;
- Have a thorough understanding of its behaviour under fault currents before and after the enhancement.

Objective:

 Investigate the electrical and consequential thermal behaviour of Z-pinned laminates under in-plane and through-thickness fault currents for the first time.



Path of the fault current through a CFRP structure







University of BRISTOL

1. Introduction

Z-pinning is an effective through-thickness reinforcement technology, by inserting small rods through the thickness of composites.

It is the primary technique used in prepreg constructions.

In recent years, there has been growing interest in exploring the multifunctional capabilities of Z-pinned composites.



Illustration of a Z-pinned laminate

Two types of pins, i.e., **copper** and conventional **carbon-fibre**, were employed at **two areal densities**.

Five categories of samples were manufactured with a **QI** stacking sequence:

- Unpinned (UP)
- Copper low-density Z-pinned (COP-L)
- Copper high-density Z-pinned (COP-H)
- Carbon-fibre low-density Z-pinned (CAR-L)
- Carbon-fibre high-density Z-pinned(CAR-H)





COP-L

COP-H







Engineering and Physical Sciences Research Council



4

Current input locations varied on the top surface from position 1 to 9, whilst the output was kept constant at the **bottom** surface.



Results:

- The through-thickness resistance was reduced by two orders with Z-pins.
- The high-density Z-pinned samples have lower resistance than low-density ones.
- The resistance of copper Z-pinned samples is higher than carbon-fibre Z-pinned samples.

Experimental plot of the through-thickness resistance









Current input locations varied on the top surface from position 1 to 9, whilst the output was kept constant at the **bottom** surface.





Experimental plot of the through-thickness resistance



ICCM23





University of BRISTOL

EPSRC Centre for Doctoral Training in Advanced Composites for Innovation and Science



Results:

The plot has a symmetric trend which is consistent with the distribution of top-surface electrodes. It implies that the current path of the top ply dominates the global result.

2. Resistance measurement



Current input location varied on the top surface from position 1 to 9,

whilst the output was kept constant at the side.

Experimental plot of the in-plane resistance

Results:

- Z-pins also reduce the in-plane resistance, although the amount is not as much as the through-thickness direction.
- In terms of the pin material and areal density influence, the discipline is the same with through-thickness direction.
- The similar top layer dominated behaviour was observed.
- The resistances associated with positions 4, 7 and 8 of Z-pinned samples are much smaller than unpinned ones.





Engineering and

hysical Sciences

earch Counci





2. Resistance measurement

Why is the resistance of copper Z-pinned samples higher than that of carbon-fibre Z-pinned ones?





Through-thickness resistance comparison with enamelled copper (ECOP) Z-pinned specimen

Fibre crimping of Z-pinned specimen

- The pin itself is **not** directly engaged in the current path.
- The fibre-to-fibre connections, instead of the pins, are the main current flow path for through-thickness conduction.







Engineering and

hysical Sciences

search Council



3. Fault current test



3. Fault current test

Through-thickness direction result

10



4. Conclusions

Summary:

- This work shows that there is a notable enhancement of the electrical conductivity of CFRP laminates with Z-pins inserted, especially in the through-thickness direction. The conductivity improvement reduces the temperature increase due to Joule heating under fault currents.
- Unlike other conductivity enhancements, such as metal meshes that have only one function and increase the laminate weight, the Z-pins also have a beneficial influence on the laminate's through-thickness mechanical properties.

Future work:

• This study is limited to static small currents. In the future, exploring the behaviour of Z-pinned laminates under other scenarios would be of interest. Additionally, electrical models are preferred to help design and optimise Z-pinned laminates in their electrical applications, as experimental cost is high if a range of parameters are considered.

Acknowledgements:

This work was supported by the Engineering and Physical Sciences Research Council through the Centre for Doctoral Training in Advanced Composites for Innovation and Science (grant number <u>EP/L016028/1</u>).





Engineering and





Mudan Chen

mudan.chen@bristol.ac.uk

+44 07395624510

+86 13685269313

bristol.ac.uk/composites





EPSRC Centre for Doctoral Training in Advanced Composites for Innovation and Science



Engineering and Physical Sciences Research Council

