EFFECTIVE REPAIR STRATEGY FOR DAMAGED FIBRE COMPOSITES IN AUTOMOTIVE: IS IT POSSIBLE?

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A BOOK ON THE MECHANICS OF CHOPPED FIBRES FOR THE BUSY ENGINEERS

- General theory of stress transfer that applies to chopped fibre reinforced composites
- How the theory can be applied to design chopped fibre reinforced composites
- Novel multi-scale approach for facilitating further developments in the field of stress transfer and fracture mechanics in chopped fibre reinforced composites

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OVERVIEW

1. Introduction to damaged composites, repair techniques, challenges
2. Effective repair: at what lengthscale are we talking about?
3. Outline of a possible strategy; preliminary findings
4. Conclusion
DAMAGE

TWO KEY CHALLENGES FOR THE AUTOMOTIVE INDUSTRY WHEN REPAIRING DAMAGED COMPOSITE STRUCTURES

Challenges for the automotive industry:

1. How to determine the extent of damage to composite structures?
2. When to decide whether to repair or replace those damaged structures?

As raw material costs for composites come down, demand for composites for cars will increase.

As the number of ‘composite-intensive’ cars increases, how should one deal with the damaged composites in road accidents?

Some composite parts may have little economic incentive to repair, e.g. hoods, trunk lids, roofs...

Critical structural components on the chassis may need to be repaired.

If most parts are severely damaged, the vehicle may be scrapped.
DAMAGE TO COMPOSITE MAY BE HIDDEN TO THE EYE

- Composite structure may show no visible signs of damage
- But internally, delamination of plies and other damage may occur!!
SUCCESSFUL REPAIRS REQUIRE SKILLED TECHNICIANS, QUALITY OF MATERIALS, REPAIR ENVIRONMENT

Patching
- Temporary or permanent, depending on application
- Damage site need not be cut away cleanly
- Wet lay-up of repair plies

Scarfing
- Good workshop, trained technician
- Cut to 50:1 taper
- Lots of good material cut out

Resin infusion
- Restores repaired composite to near-design compressive and shear strength through resin injection
- Inexpensive!!
- Internal cracks must be contaminant-free

From 'Repair of Fibre Reinforced Polymer (FRP) Structures', National Composites Network Best Practice Guide by Dr Sue Halliwell, NetComposites
WHAT ARE THE KEY CONSIDERATIONS FOR QUALITY CONTROL OF REPAIR PROCEDURES?

• **Assessment:** Many non-destructive inspection techniques available to help determine the extent and degree of damage.

• **Cost:**
  1. Once the extent and seriousness of damage has been assessed a decision can be made on how quickly it needs to be repaired.
  2. It is the additional costs that surround a repair that affects how a repair should be undertaken.

• **Environment:** If a repair is to be carried out immediately to prevent further damage, a (environment) controlled work area must be made available to provide either a temporary or permanent solution.
LIMITATIONS TO CURRENT REPAIR TECHNIQUES FOR FIBRE REINFORCED COMPOSITES

• **Criticality of the damaged structure:**
  1. The more primary a composite structure is, and the closer it operates to its design limits, the more difficult the repair
  2. Heavily loaded, oriented-fibre, advanced composite structures require careful engineering design of major repairs; it is not simply a matter of applying a patch

• **Understanding the details:** Repairs can be time-consuming, and calls for attention to **structural** details but what are they?

• **Fundamental principles:** Quality assurance involves a good understanding of underlying principles and the testing required to ensure the repair will be successful long-term
FUNDAMENTALLY FIBRE REINFORCED COMPOSITE IS A MULTI-SCALE MATERIAL, NOT MONOLITHIC
EFFECTIVE REINFORCEMENT MUST ADDRESS LENGTH SCALE FROM MACRO TO MOLECULAR LEVEL

Macroscopic

Fibre level

Fibre-matrix Interface

Molecular

Daniel & Ishai, Engineering mechanics of composite materials, 2006

E.g. stresses in chopped fibre
DAMAGE IN CFRP MUST ADDRESS FROM MACRO TO THE LOWEST POSSIBLE LENGTH SCALE

- Macroscopic
- Fibre level
- fibre-matrix Interface

![Diagram showing macro-crack, micro-crack, and stress-strain curves](image)

Daniel & Ishai, Engineering mechanics of composite materials, 2006

- Composite stress versus strain
- E.g. stresses in chopped fibre
EFFECTIVE REPAIR MUST ADDRESS FROM MACRO TO THE LOWEST POSSIBLE LENGTH SCALE

Macroscopic

Fibre level

sealed micro-crack

fibre-matrix Interface

Molecular

Daniel & Ishai, Engineering mechanics of composite materials, 2006

E.g. stresses in chopped fibre
NATURE TELLS US THAT… DAMAGED SOFT CARTILAGE CAN BE REPAIRED BY INFUSING COMPATIBLE SOFT MATERIAL AND CELLS

- Particle-reinforced scaffolds for soft material
- Injecting the cell-seeded scaffold into the cartilage
- Let natural healing takes its course

Stem cell therapies for treating osteoarthritis: Prescient or premature?
by Deanne J Whitworth, T. A. Banks
The Veterinary Journal 202 (2014) 416–424
NATURE TELLS US THAT… DAMAGED BONE CAN BE REPAIRED BY INFUSING COMPATIBLE BONE MATERIALS

Development of Novel Bone Substitute Biomaterials Showing Highly Osteoconductive Property

http://www.rpip.tohoku.ac.jp/seeds/profile/178/lang:en/
REDESIGNING RESIN USING NANOFILLERS/EPOXY WITH MECHANICAL PROPERTIES COMPATIBLE WITH THE COMPOSITE, AT MICROSCOPIC LEVEL

- Nanofillers/epoxy to fill microcracks in Barely Visible Damaged composites, by resin-injection
- Mechanical properties of resin at microscopic level
Fracture study to reveal unique patterns that can tell us how the fracture depends on the number of plies, speed of impact, etc..
REDESIGNING LOW PRESSURE RESIN INJECTION SYSTEM FOR EFFECTIVE FACILITATION OF NANOFILLERS/EPOXY CONTACT WITH INTERIOR CRACK SURFACES

• Resin Infusion/Injection Systems for Barely Visible Damaged composites

(a) Mark 1

(b) Mark 2

(c) Mark 3
EFFECTIVENESS OF THE FLOW OF RESIN INTO MICROCRACKS IN BARELY VISIBLE IMPACT DAMAGED COMPOSITES

Impact profile

Damaged laminate

Repaired laminate
OPTIMIZING AIR EVACUATION STRATEGY SUCH AS VENT HOLES IN THE BARELY VISIBLE DAMAGED COMPOSITES

- Vent holes for facilitating air/contaminant extraction
- Vent holes should have little effect on the mechanical properties of the laminates
REDESIGNING TOMORROW’S COMPOSITE VEHICLE FOR EFFECTIVE REPAIR

A hybrid self-healing/resin-injection strategy
ULTIMATE CHALLENGES FOR EFFECTIVE REPAIR OF CRITICAL COMPOSITE STRUCTURE IN AUTOMOTIVE

To develop easy inexpensive methods to

1. assess damage to the structural components
2. repair the structures
CONCLUSION

1. Introduction: damaged composites, repair and challenges
2. Fibre composite fundamentals for understanding the multi-scale nature of composite and lengthscale of repair
3. Preliminary findings for a new resin-injection repair technique
4. The future of composite repair
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