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Background

Structural composites are made from fibers enmeshed in a cured resin matrix. The orientation of the fibers and chemical adhesion play fundamental roles in the performance of composites, which makes failure analysis a multidisciplinary activity involving chemical processing during a structure's fabrication as well as the nature of the fractures in the failed structure.

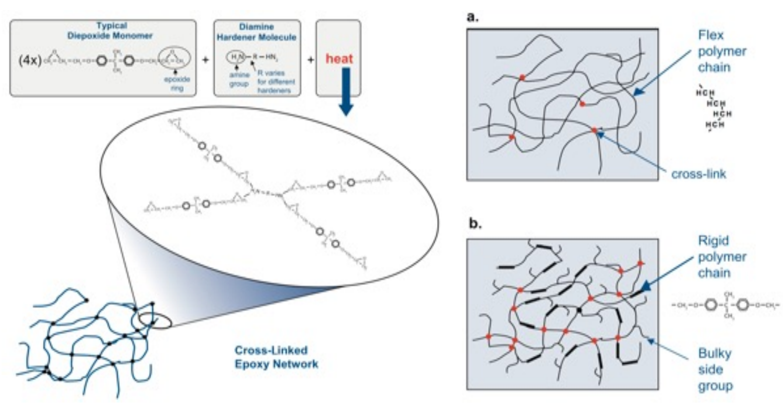
Dr. Fildes has investigated a variety of failures involving composites including aircraft fuselages, wings, and blades, and composites used in construction and the infrastructure such as laminates, wood, and composite bridges and walkways. Dr. Fildes' physical chemistry, materials science, and chemical engineering background is well suited for the multidisciplinary nature of these investigation involving chemistry, adhesion, mechanics, and chemical processes.

Dr. Fildes' research at Northwestern University was the basis for establishing Northwestern's federally-funded Advanced Composite Materials Intelligent Processing Center of which Dr. Fildes was the co-director. His composites research has also won funding in highly competitive competitions such as DARPA's Technology Reinvestment Program. Dr. Fildes also organized and led multimillion-dollar composites R&D collaborations involving major aerospace composites, leading Government labs, the Army, the Navy, the Defense Advanced Research Projects Agency, and leading suppliers of composite products and technology.

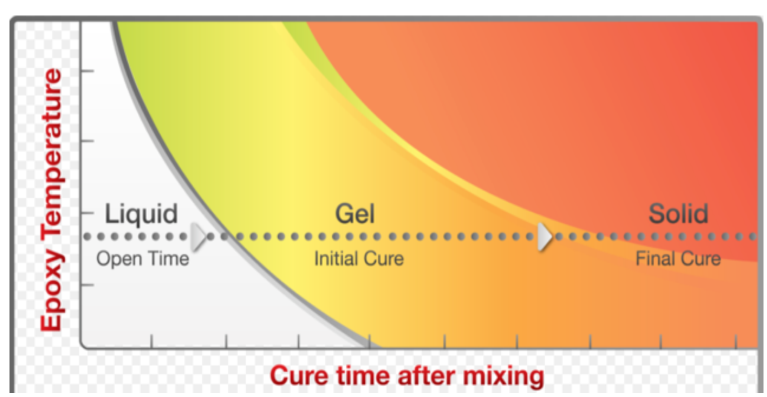
Dr. Fildes' composites research has addressed cure chemistry and processing of resins, aging and water degradation of composite resins, adhesion in composite sandwich structures, model-based control of resin transfer molding, resin flow monitoring, characterization of resins using impedance spectroscopy and infrared spectroscopy, and artificial intelligence model-based process control.

Composites Failure Analysis Is Multidisciplinary

The resins used in composites are multicomponent systems that cure through several competing reactions that cause the lengthening of molecular chains at the earlier stage of cure (a in the figure below) and crosslinking of molecular chains at the later stage of cure (b in the figure below). The length of molecular chains significantly influences the toughness (i.e. lack of brittleness) and the amount of crosslinking controls the strength and stiffness of a composite structure.



The relative rates of chain lengthening and crosslinking over time is controlled by chemicals called hardeners and possibly accelerators and by the temperature profile of the cure cycle. The viscosity of the resin first decreases and then increases over time as shown by the figure below. Pressure is applied when the viscosity is low to consolidate the composite and remove air bubbles.



For questions, or more information, please contact John Fildes, Ph.D. at (630) 248-0836 or jfildes@SpotlightBC.com

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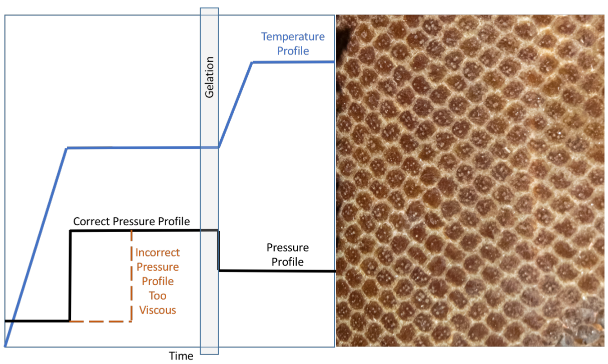
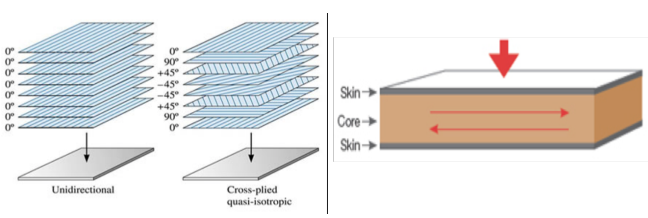
Composites Processing and Fabrication

Dr. Fildes has investigated composite failures where the required pressure and temperature profiles were not followed during a structure's fabrication. This can result in a structure not achieving the design strength, especially if the resin becomes too viscous before pressure is applied, which can result in inadequate compaction, stiffness, and strength. Bubbles in the cured resin suggest this type of failure mechanism.



Failure Analysis of Structures

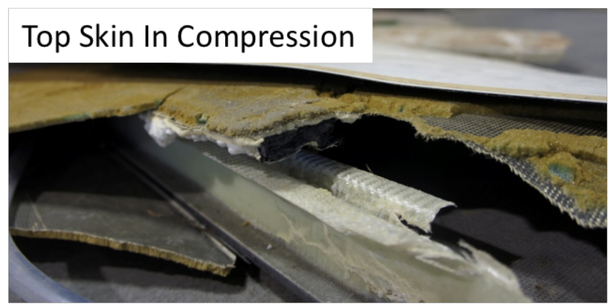
Dr. Fildes has investigated failures of laminate composites and composite sandwich structures due to helicopter and aircraft accidents.

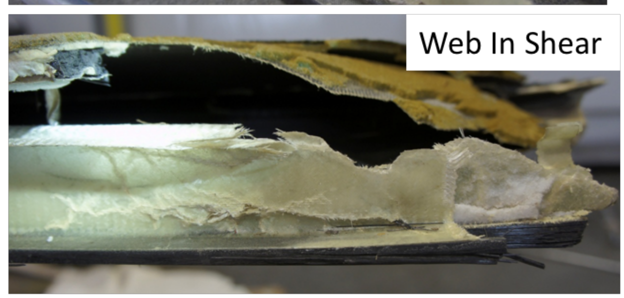


His investigations have been related to helicopter blades, wings, and fuselage structures, with suspected causes due to manufacturing defects, collisions, and degradation of adhesives due to thermally based repair processes.

A common issue in failure analysis of composite structures involved in accidents is to determine if a failed structure was the origin of the accident or if the failed structure resulted from the accident.

For example, the nature of the tears in a composite sandwich structure can reveal the origin of the failure. The figures below show a sandwich structure in which the top skin fractures have relatively smooth surfaces. The bottom skin fractures have rough surfaces with fiber pullout and delamination in two planes due to the use of a unidirectional fiber architecture to minimize weight. The skin also shows tears that run 45 degrees to the chord, which indicates torsion of the structure. The web also shows a shear failure that is consistent with torsion.





This set of features indicates that the failure resulted in an overload of the structure that likely was the result of the accident.

Dr. John Fildes has a Ph.D. in physical chemistry, a B.S. in chemistry, and he was a post-doctoral research associate in a chemical engineering department. Physical chemistry provides the scientific basis for many engineering disciplines. Dr. Fildes has conducted over $27.5 million of R&D and/or litigation-related investigations. He led large groups of scientists and engineers at two scientific/engineering firms licensed to practice professional and structural engineering that conducted thousands of litigation-related technical investigations, so he is also an expert in the conduct of these types of investigations.