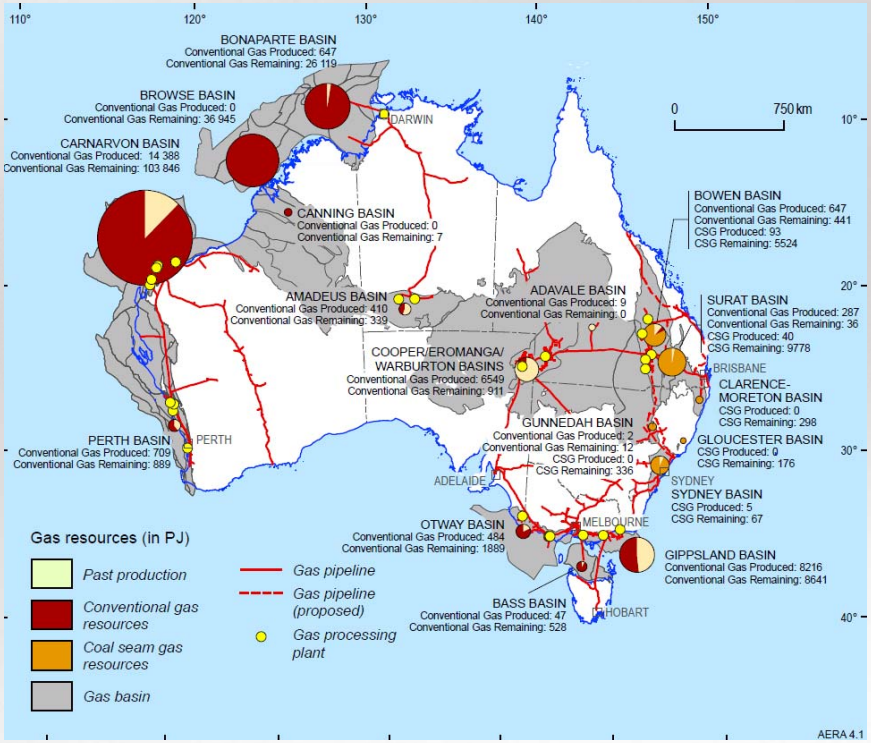
Design, Analysis and Manufacture of a Novel Compressed Natural Gas Storage Vessel for Automotive Applications

CNG background

- CNG supply
  - Conventional gas reserves of 63 years
  - New gas discoveries
  - Unconventional gas



Geoscience Australia

CNG background

- CNG in automotive
  - Low emissions
  - Low cost
  - Widely adopted/proven
  - Bridge between petrol and EV's?

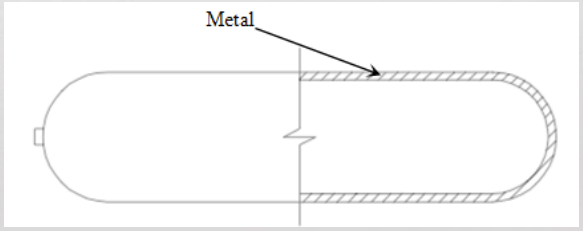
CNG background

- How can an improved CNG storage vessel design increase adoption?
  - Weight reduction
  - Increased operating pressure
  - Vehicle integration / volume efficiency
  - Cost

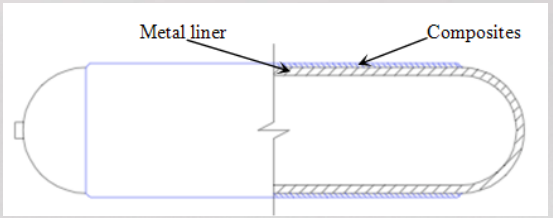
Market overview

- Conventional cylinders

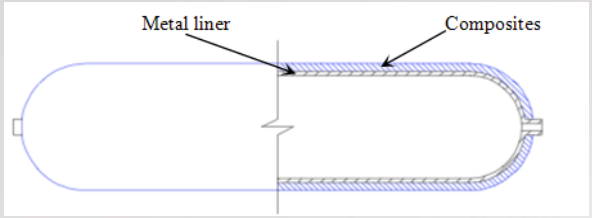
Type I: metal



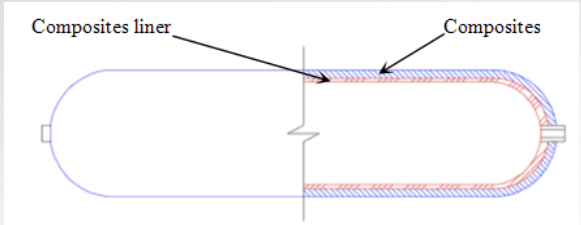
Type II: composite hoop-wrap



Type III: composite wrap



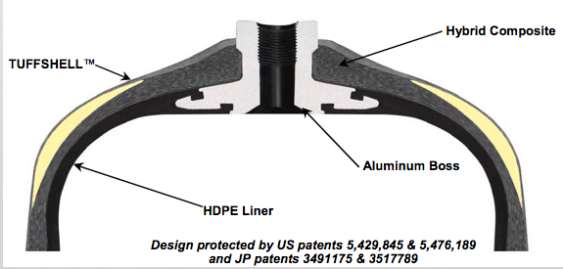
Type IV: composite



Baker

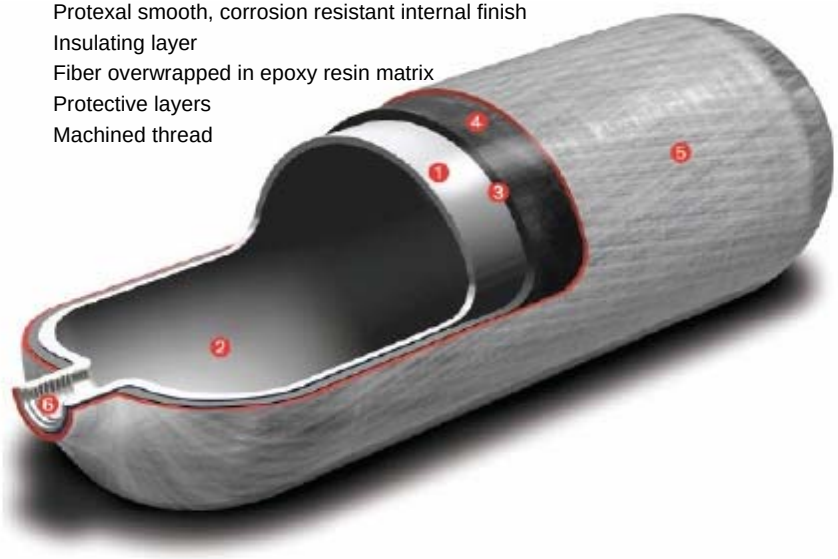
Market overview

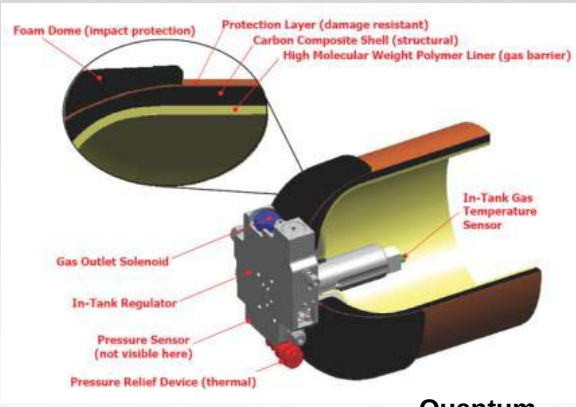
- Weight reduction
  - Composite materials
  - Innovative combinations



Lincoln Composites

1. Ultra thin-walled aluminium liner
2. Protexal smooth, corrosion resistant internal finish
3. Insulating layer
4. Fiber overwrapped in epoxy resin matrix
5. Protective layers
6. Machined thread



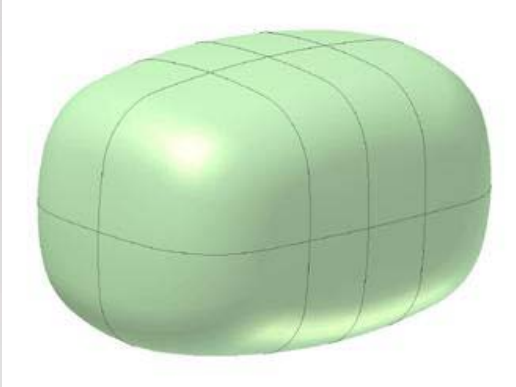


Quantum

Market overview

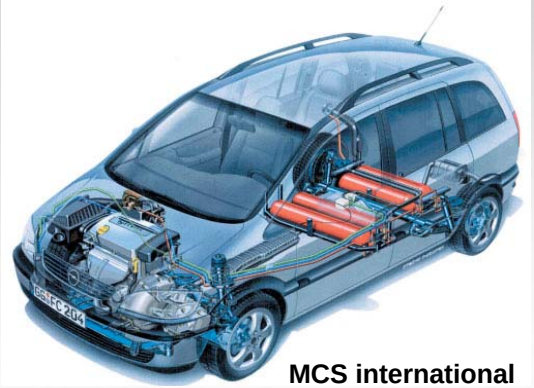
- Volume efficiency /vehicle integration
  - Conformable and eccentric: rectangular spaces
  - Toroidal: spare wheel voids

Thiokol



GasTank Sweden

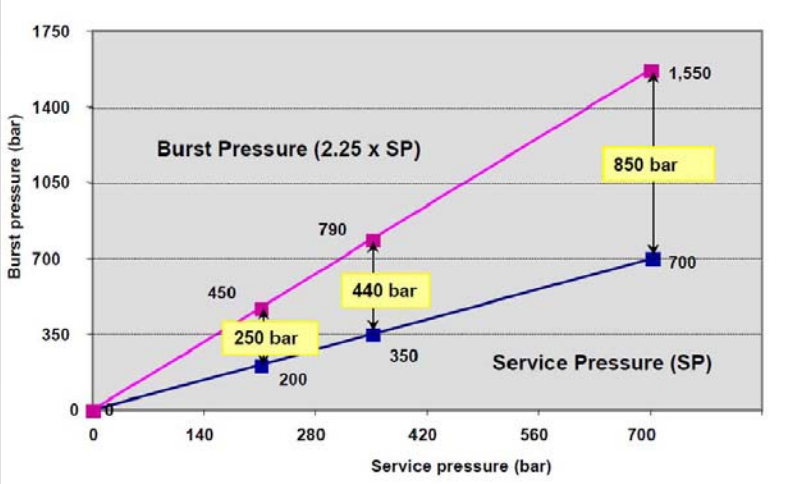
San Diego Composite



MCS international

Market Overview

- Operational Pressure
  - 250 bar current benchmark
  - Are higher pressures achievable?



Powertech

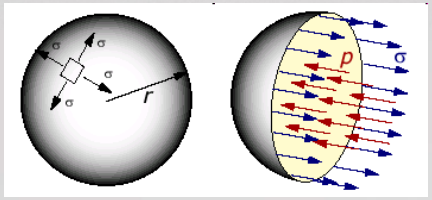
Market Overview

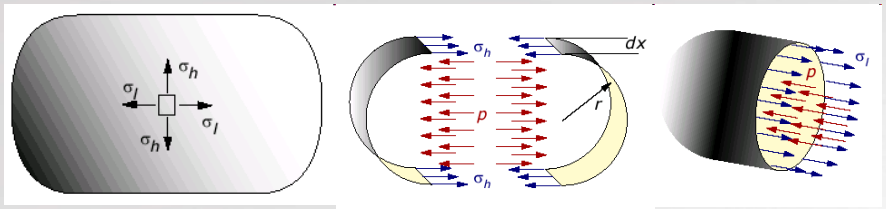
- Cost
  - While type 1 all metal vessels can cost as low as 25% of typical type 3 and 4 vessels, they can also weight over 4 times the amount of an equivalent all composite vessel.

Shenyang

Design concepts

- Optimise cylindrical designs
  - Cylinders well suited to pressure loads
  - Can improvements be made?





eFunda

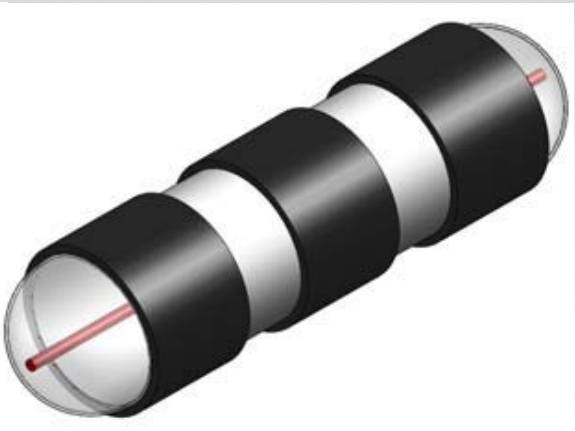
Lincoln Composites

Design concepts

- Optimise cylindrical designs
  - Internal bracing
  - Reduce / optimise composite reinforcement
  - Lighter materials, higher pressure, lower cost?

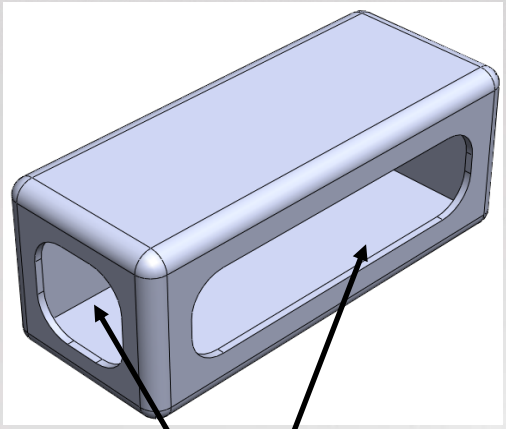

Hoop wrap

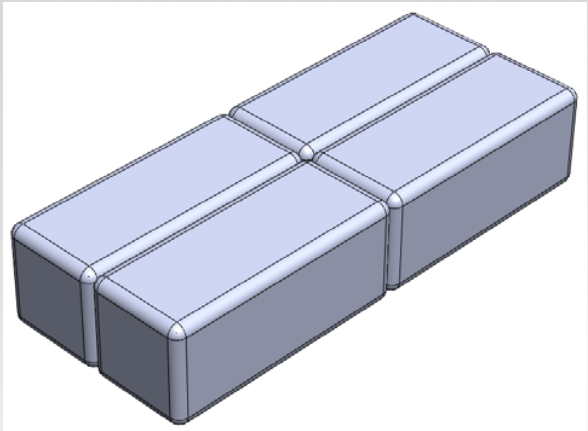

Full wrap


Banded

Design concepts

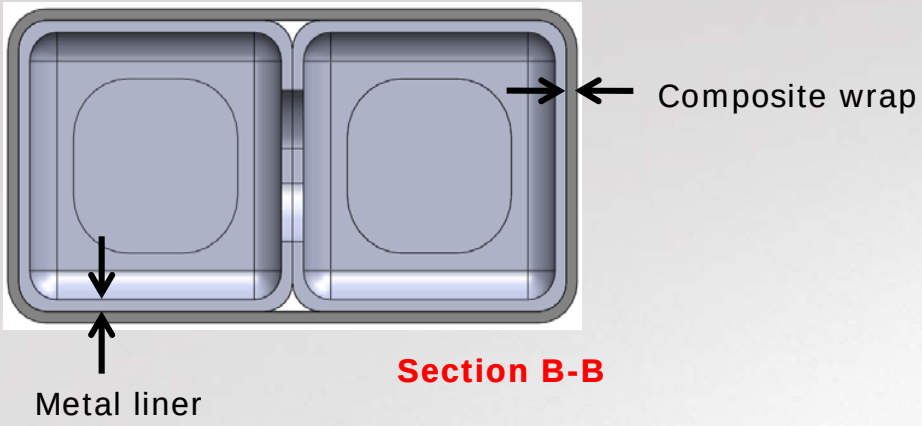
- Modularity
  - Flexibility to tailor to a range of design spaces
  - Internal bracing for rectangular sections

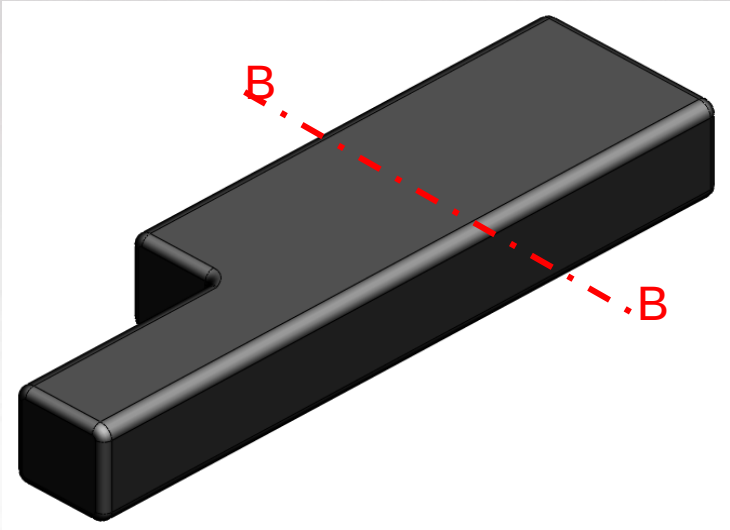




Design concepts

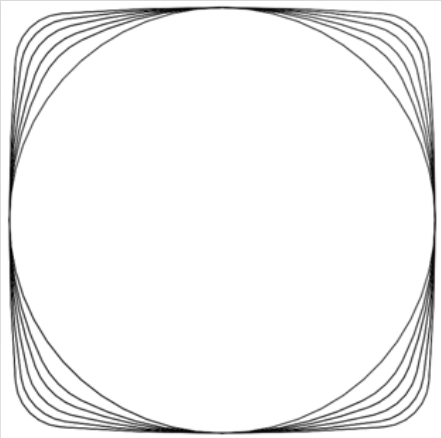
- Modularity
  - Composite wrap option
    - still suffers from excessive material requirements and difficult to manufacture

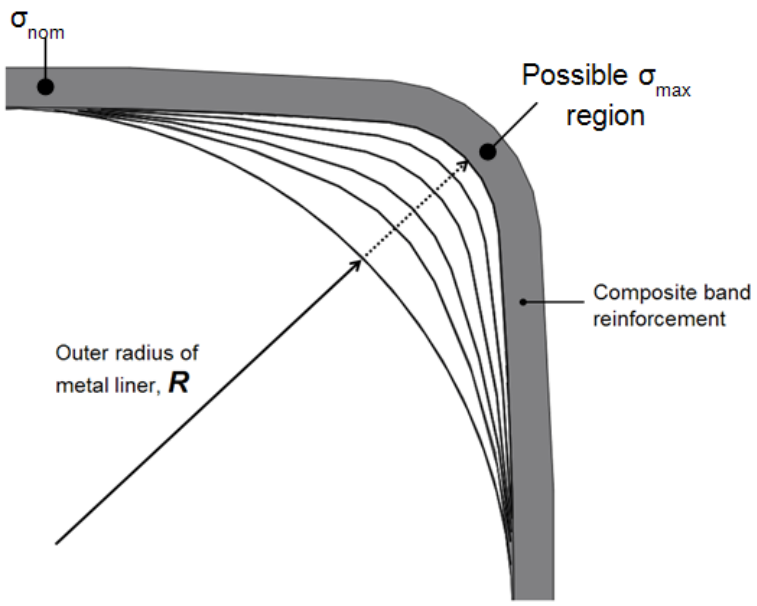




Design concepts

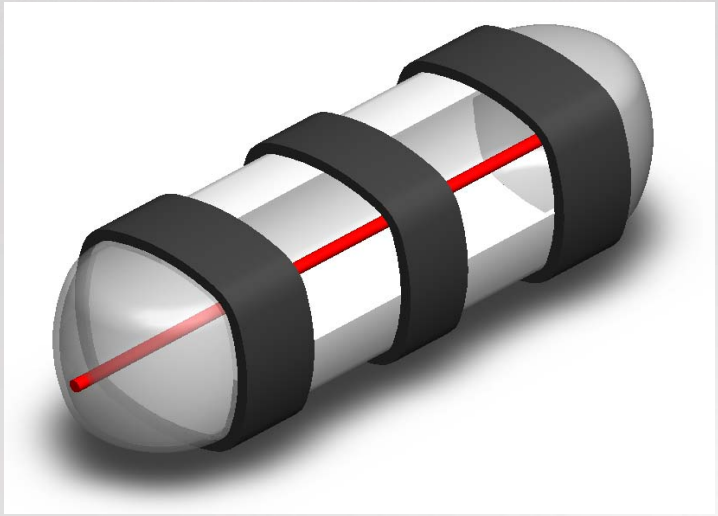
- Non-cylindrical structures
  - Increased volume efficiency
    - Stress concentrations in high curvature regions

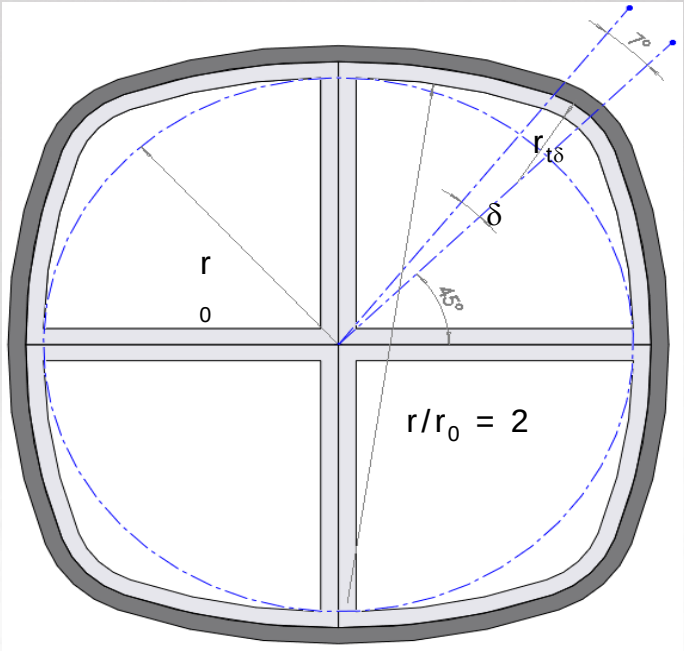




Design concepts

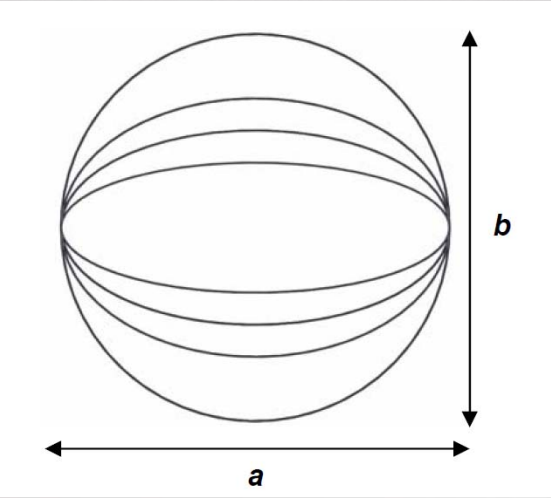
- Non-cylindrical structures
  - Eccentric designs
    - GasTank concept exists
    - Other improvements?

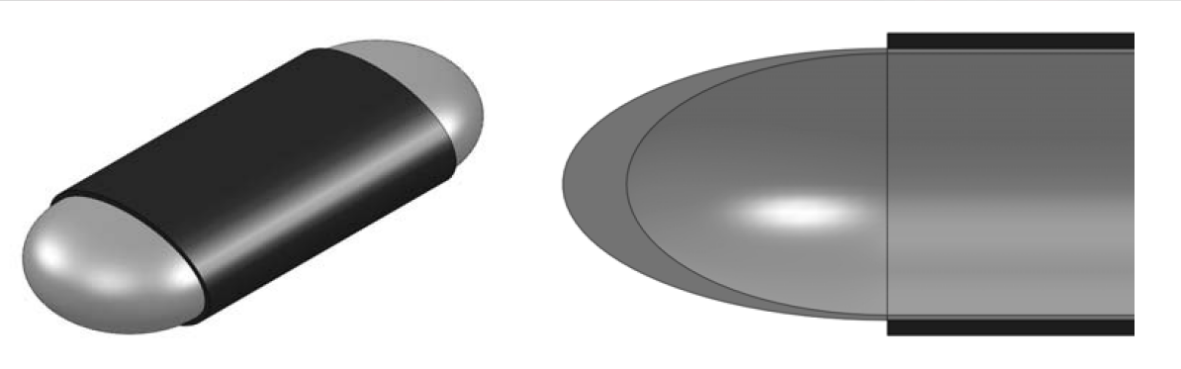




Design concepts

- Non-cylindrical structures
  - Elliptical design
    - Selective reinforcement = less weight penalties
    - Further analysis required for concept validation

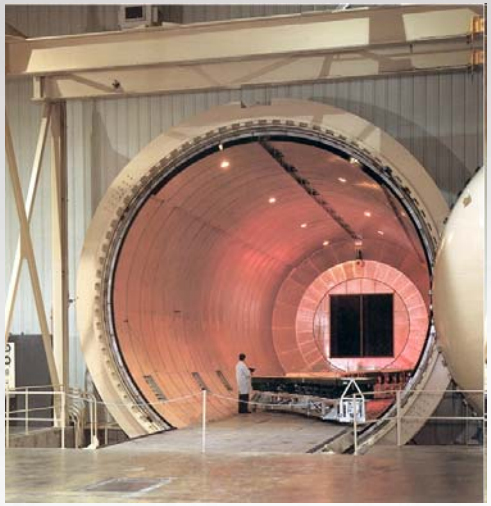




Advanced composite materials

- Existing materials and approaches
  - Fibre reinforced thermosets
  - Filament winding
  - Autoclave

Entec



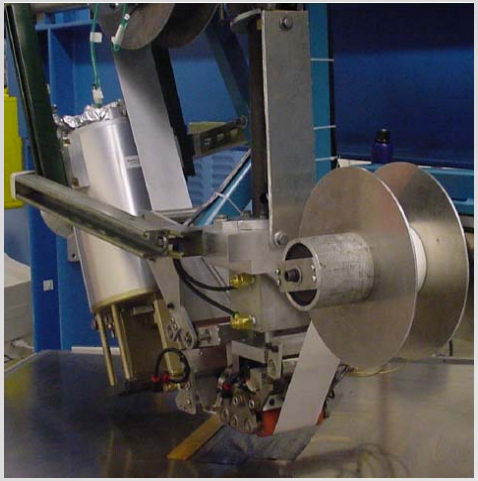
Raytheon

Advanced composite materials

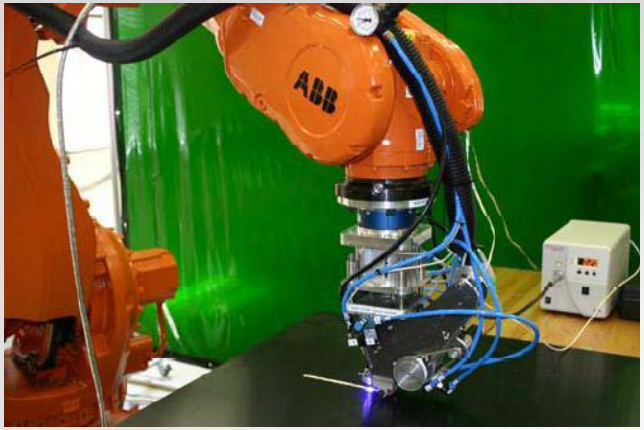
- High performance thermoplastics
  - Better fracture toughness and fatigue behaviour
  - High glass transition temperatures
  - Excellent chemical resistance
  - Can be re-melted and re-cycled
  - Ability to form rapid bonds

Advanced composite materials

- Continuous in-situ processing
  - Robotic fibre placement
  - Rapid localised processing
  - Efficient and flexible



Nasa Langley

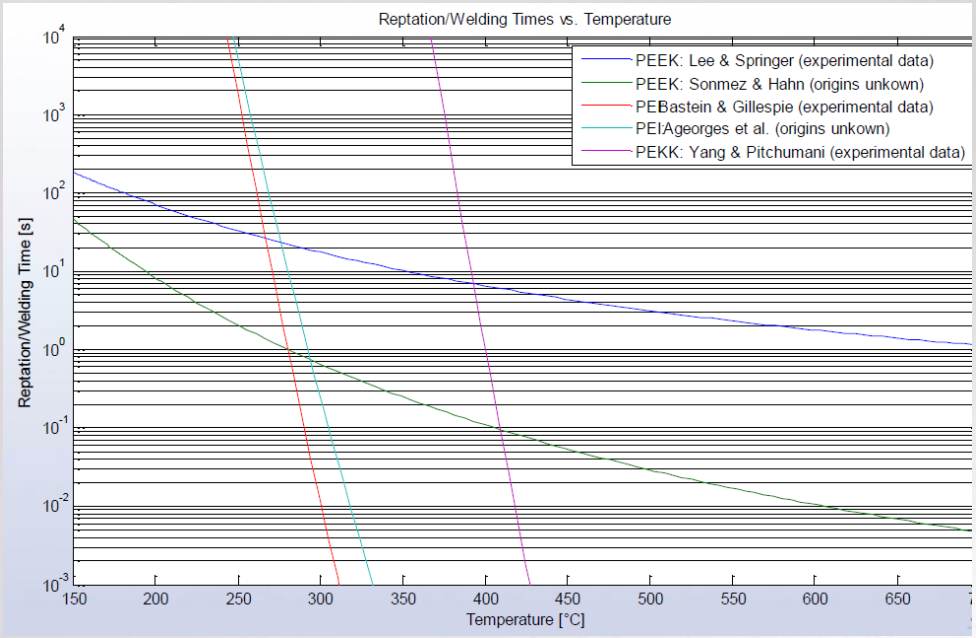


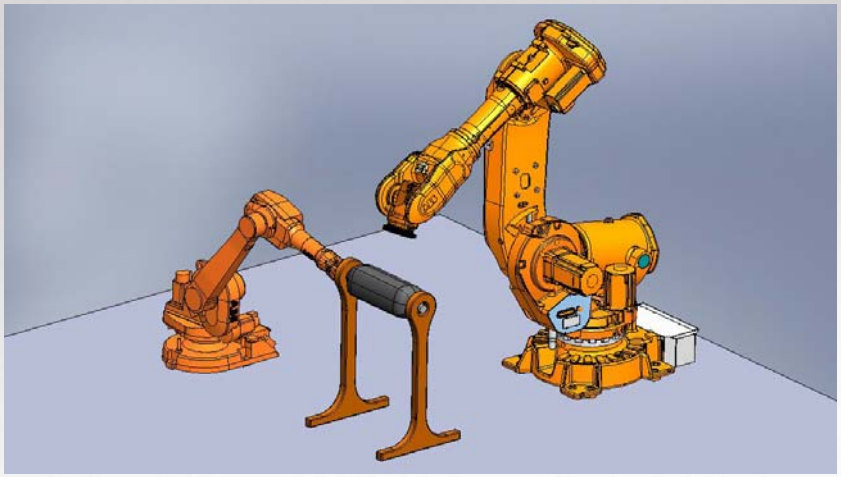
Australian National University

AFPT

Advanced composite materials

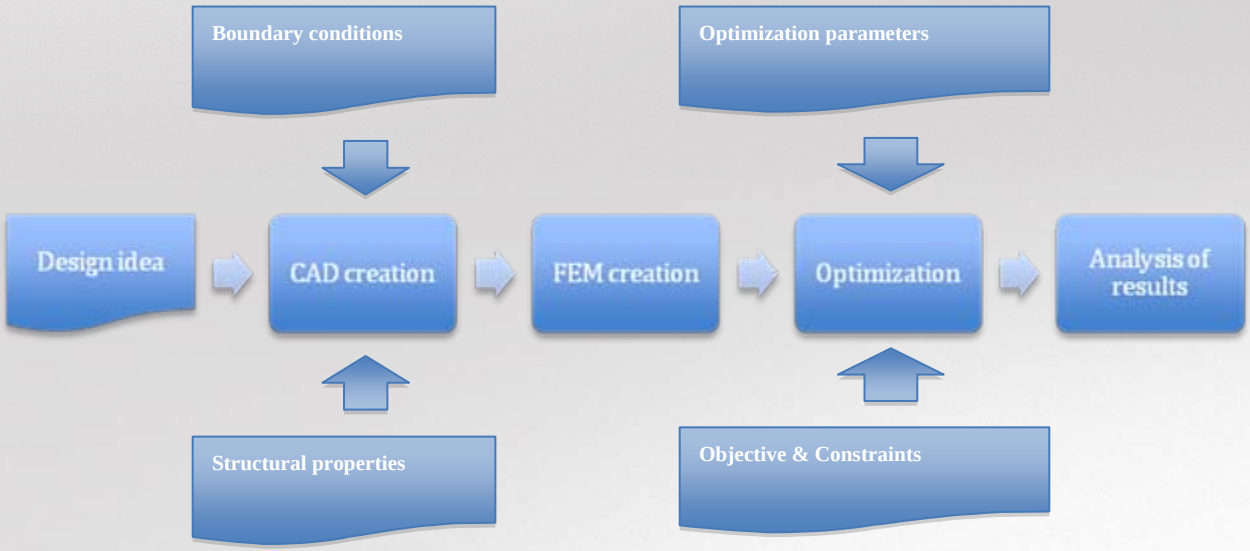
- Continuous in-situ processing
  - Thermoplastics: rapid bonding potential
  - Flexible manufacturing





Virtual analysis

- Structural analysis
  - Virtual analysis and optimisation



Virtual analysis

- Structural analysis
  - CAE tools
    - Linear Finite Element Analysis (FEA)
    - Nonlinear FEA
    - Fatigue analysis
    - Optimisation
      - Topological
      - Free-shape
      - Design of Experiment

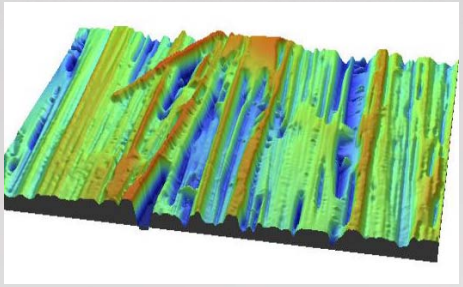
Virtual analysis

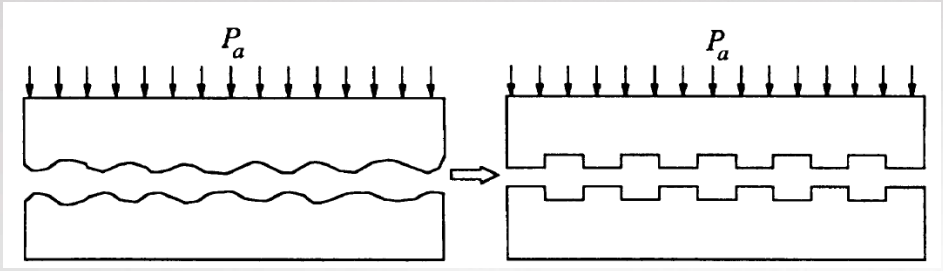
- Structural analysis
  - Virtual tests: cost effective
    - Hydrostatic burst
      - Nonlinear FEA
    - Pressure cycling
      - Linear FEA and subsequent fatigue analysis
    - Bonfire
      - Temperature-dependent behaviour
    - Bullet penetration
      - Post-impact analysis more efficient

PowerTech

Virtual analysis

- Manufacturing process models
  - Degree of bond
    - Intimate contact must first be established

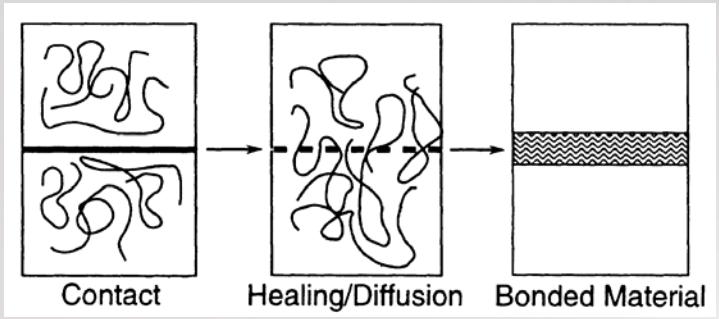




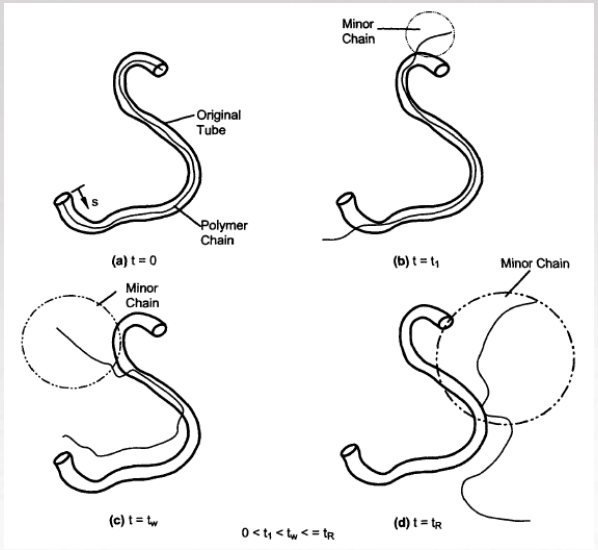
Butlerand

Virtual analysis

- Manufacturing process models
  - Degree of bond
    - Molecule diffusion, or fusion bonding can then occur

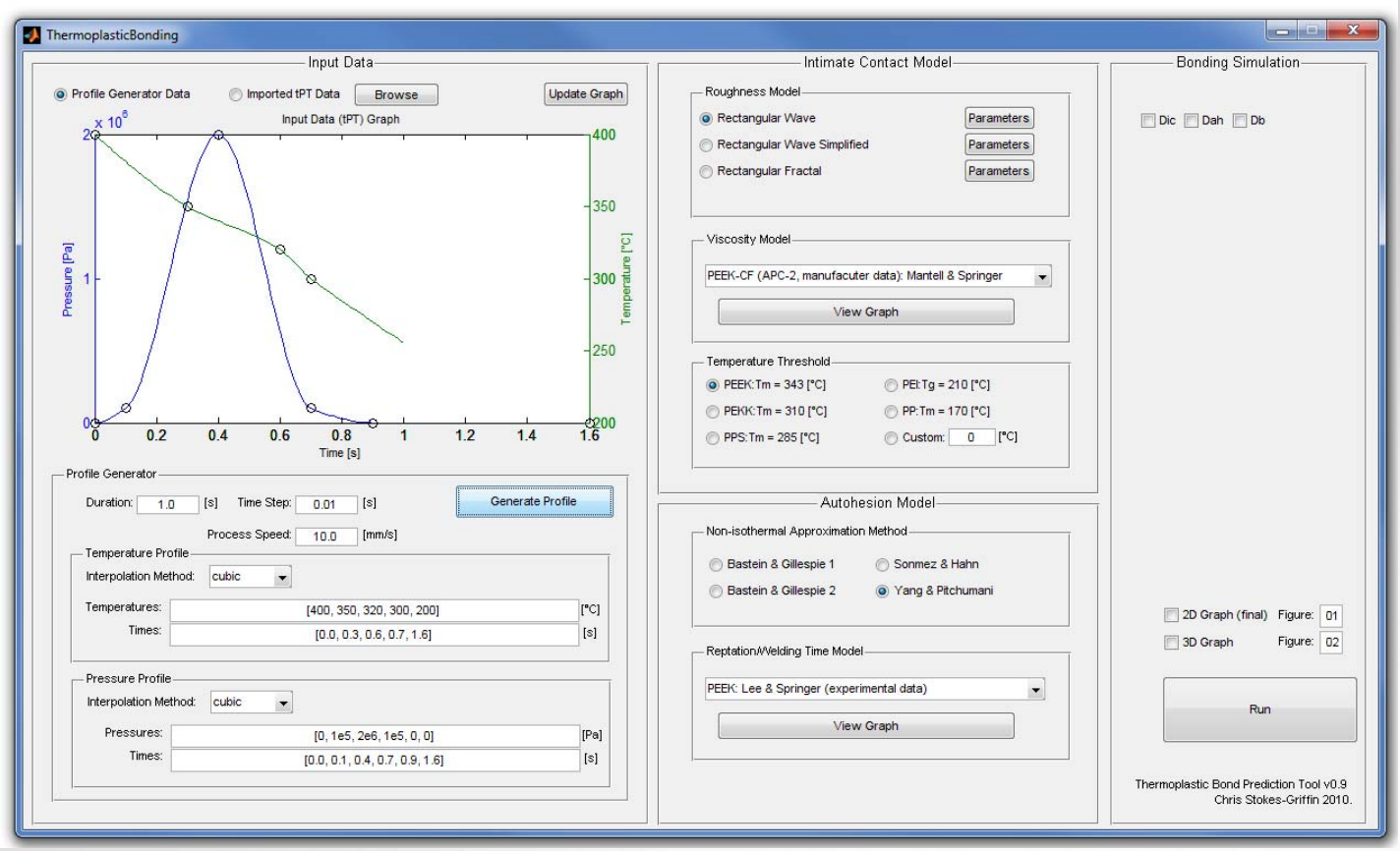


Sonmez



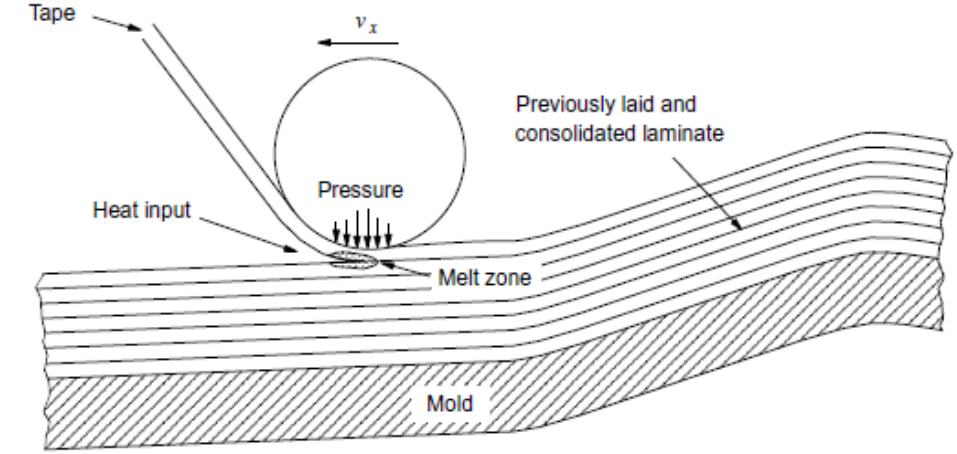
Virtual analysis

- Manufacturing process models



Virtual analysis

- Manufacturing process modelling
  - Placement head optimisation
    - Pressure distribution, lay rate, temperature, tape dimensions, component dimensions, lay path, etc…



Sonmez

Conclusion

- Design
  - Elliptical design with selective reinforcement
    - Volume efficiency, higher pressure, avoid stress concentrations
    - However, more composite specific analysis required
- Advanced composites
  - Thermoplastics
    - Weight reduction, superior material properties, more efficient manufacturing processes
- Virtual analysis
  - Structural and manufacturing process models
    - More efficient design cycles
    - Better products and processes