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Review of Textile Composite Materials on Automotive Industry

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Background

- In the past, the purpose of weight reduction was to achieve better performance in automotive industry.
- In 1988, Ford and Budd demonstrated a lightweight car, which replaced most metallic components (except powertrain and suspension) with graphite reinforced composites. They achieved significant weight reduction (33% or 570 kg). However the cost was unacceptable for commercial market.

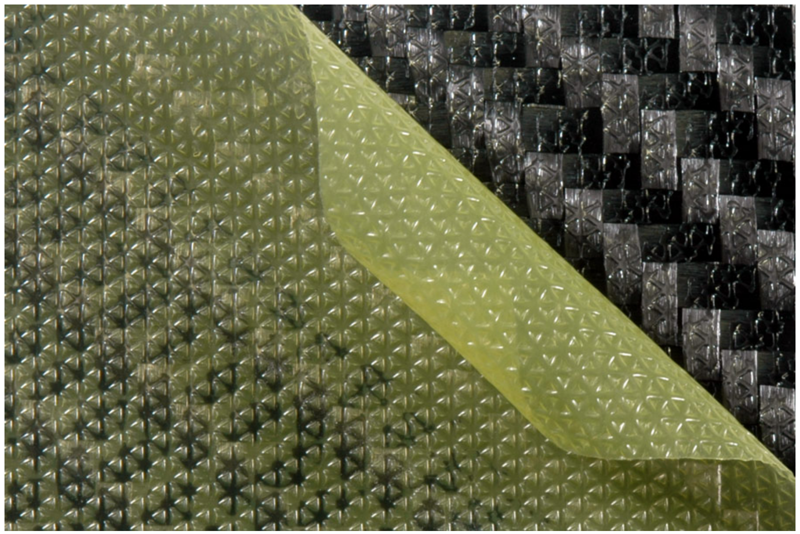
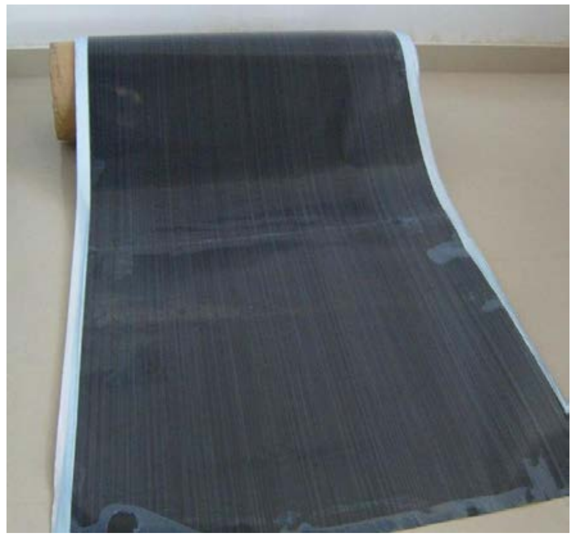
Ford LTD composite car

Background

- Recent years, reducing vehicle weight for cutting down CO_2 emission and achieving fuel-efficiency has become a general design concept.
- European Union (EU) has set a CO_2 emission target of 95 g/km for all new cars by 2020 (120 g/km by 2012).
- The increasing demand of light weight materials for automobile which opens a new commercial market for high performance composites.

2D FRP composites

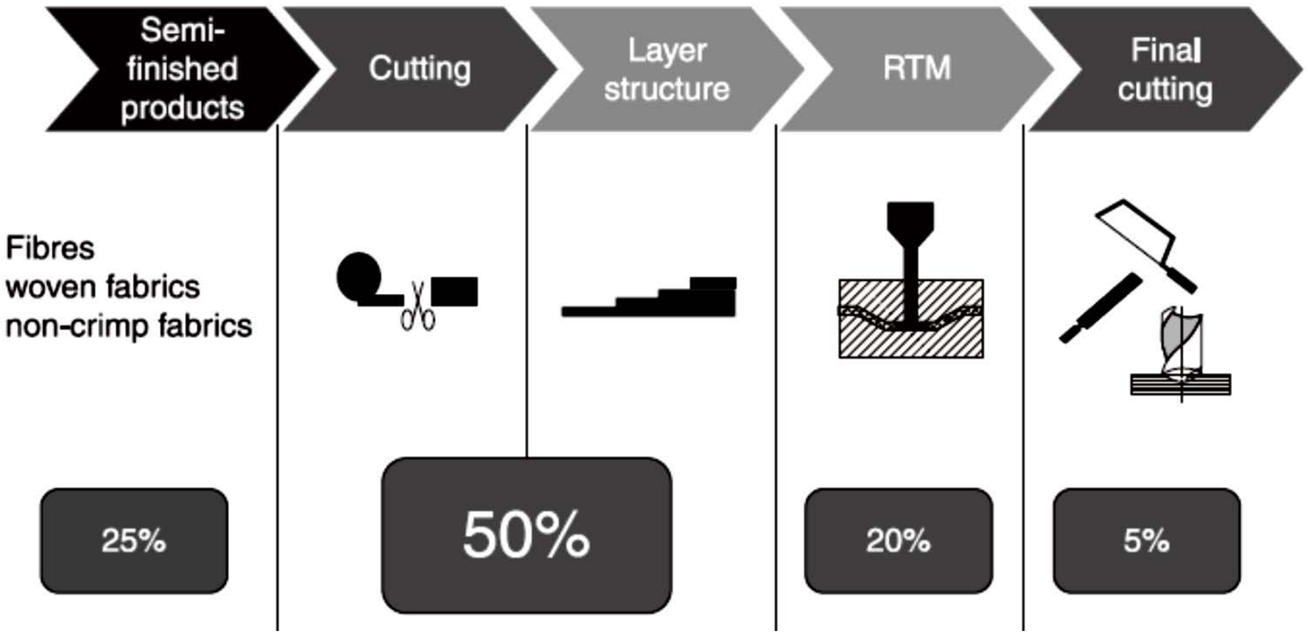
- Have been developed for more than 50 years.
- **Fibre alignment:**
  - Unidirectional (UD) fibre, woven fabric.
- **Reinforcement geometry:**
  - Laminate

Woven and UD prepreg

2D FRP composites

- Delamination
- Joint process required (for complex structures)
- High manual work required



Cost distribution in manufacture preform system composites (B. Kock-Hartmann, 2011)

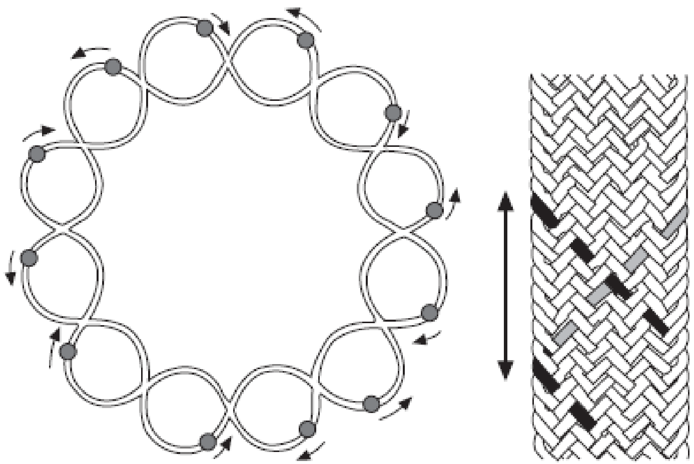
3D textile composites

- Developed in the late 1960s.
- Features
  - Better inter-laminar mechanical properties
  - Near-net-shape textile preform
  - Single step preform fabrication
  - Can be highly robotic
- Fabrication techniques
  - Braiding
  - Weaving
  - Knitting

3D textile composites - Braiding

- **Producible structure:**
  - Tubular or beam.
- **Fibre architecture:**
  - ±θ° interlocked fibre yarns along axial direction.

3D braided L-beam

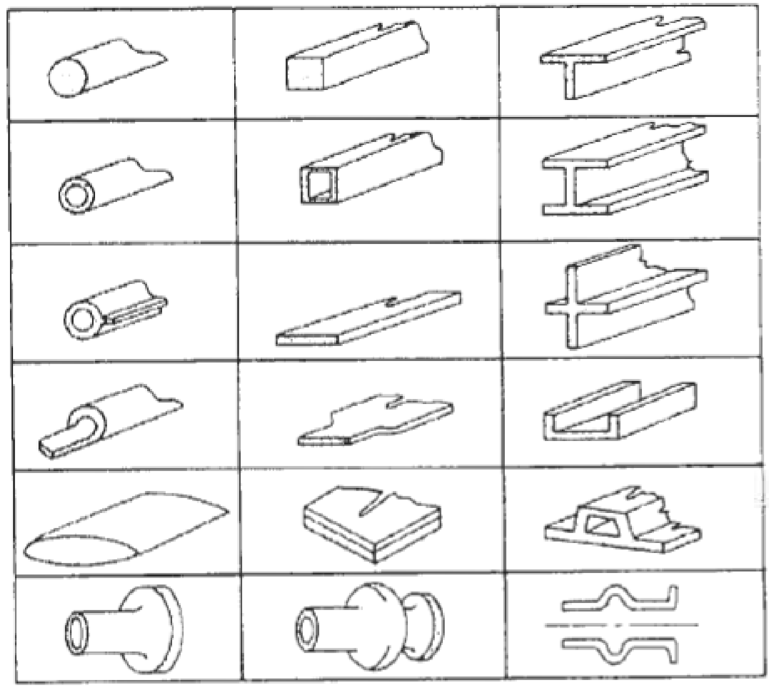


Woven and UD prepreg (S. Lomov, 2005)

Braided vehicle component

3D textile composites - Braiding

- Good torsional stability, shear resistance.
- Cost-efficient way to produce near-net-shape textile preforms.
- Lower longitude stiffness.
- Difficult to produce large cross-section structures.



Possible 3D braided composite structure (L. Tong, 2002)

3D textile composites - Weaving

- **Producible structure:**
  - Beam, panel, tubular.
- **Fibre architecture:**
  - Two-dimensional multilayer fabrics with z-directional binding fibre yarn.

Jacquard weaving machine

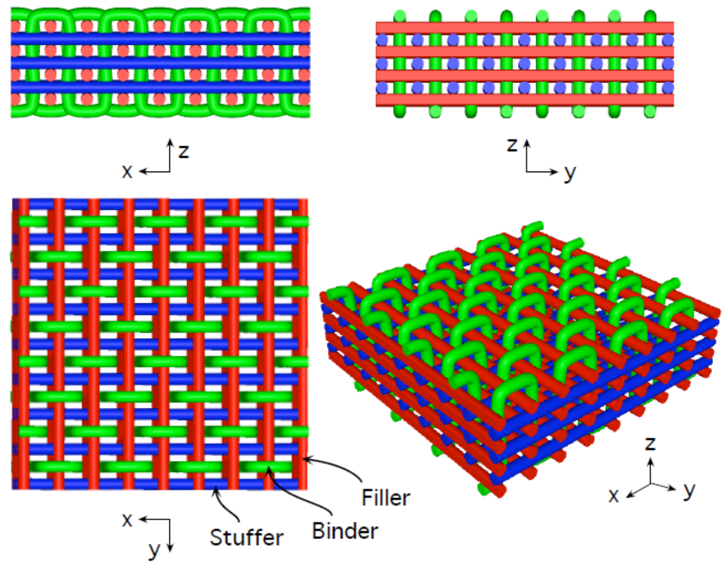
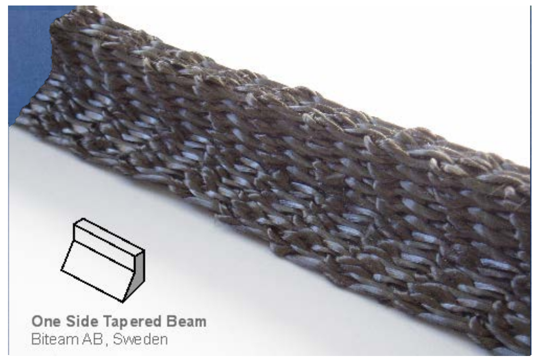


Illustration of 3D woven structure (F. Stig, 2012)

3D textile composites - Weaving

- One-step preform production with z-directional reinforced fibres.
- High inter-laminar properties and impact tolerance.
- In some cases, jacquard machine can be modified into 3D weaving machine.
- Fibre crimp can affect the longitudinal Young's modulus.

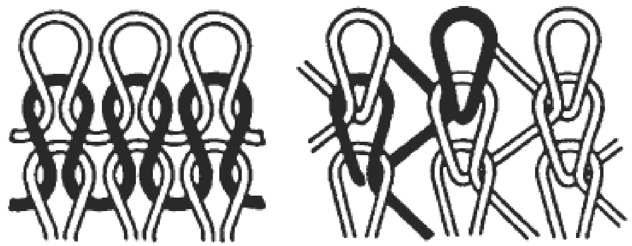
3D woven preform and molded product (McClain, 2012)



3D woven preforms (Biteam)

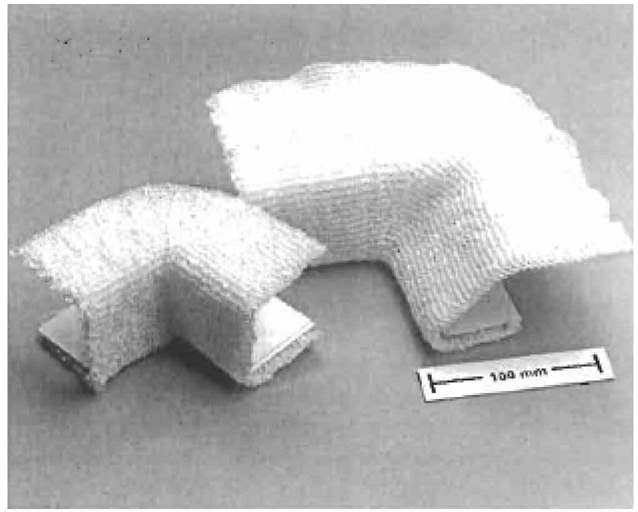
3D textile composites - Knitting

- **Producible structures:**
  - Complex 3D shapes.
- **Fibre architecture:**
  - Interlocked fibre loops (highly crimped).



Basic knitting yarn structure
(L. Tong, 2002)

- Material waste can be minimised.
- Sophisticate in manufacture and time consuming.



3D knitted preform (L. Tong, 2002)

3D textile composites - NCFs

- **Non-crimp fabrics (NCFs)**
  - Non-woven fabric.
- **Producible structures:**
  - 2D shapes, curves
- **Fibre architecture:**
  - Unidirectional fibre layers.
  - Knitting yarns act as z-directional binder.

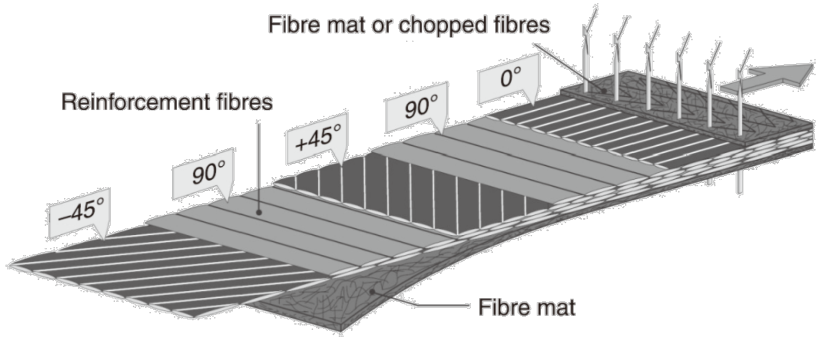
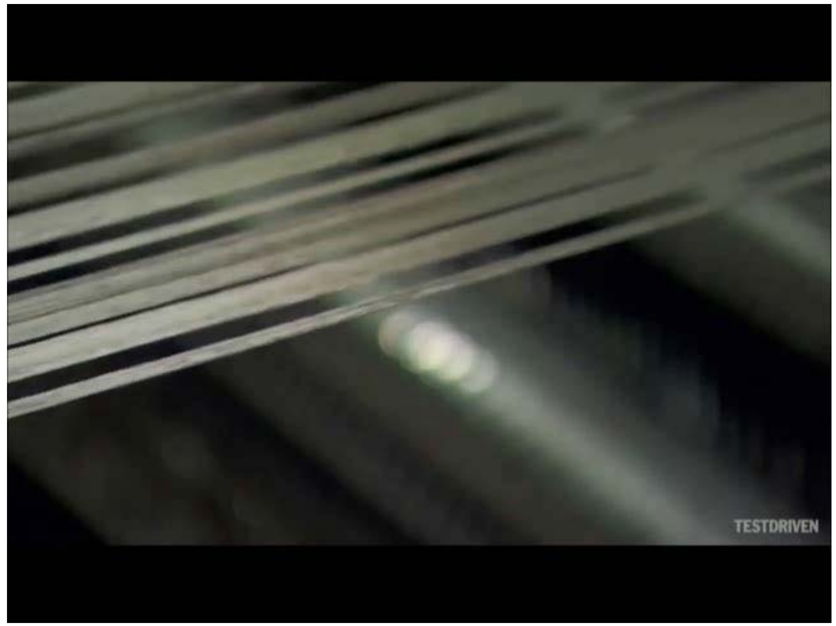


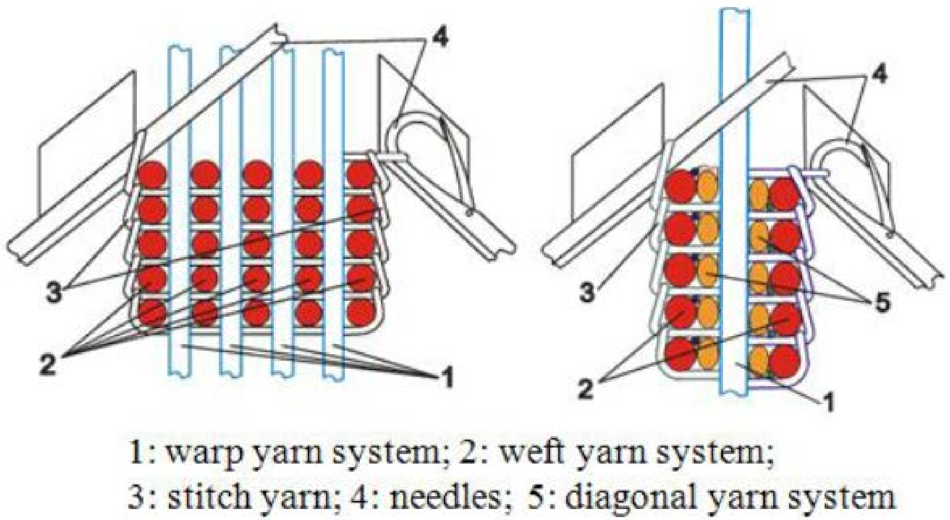
Illustration of NCF (S. V. Lomov, 2011)

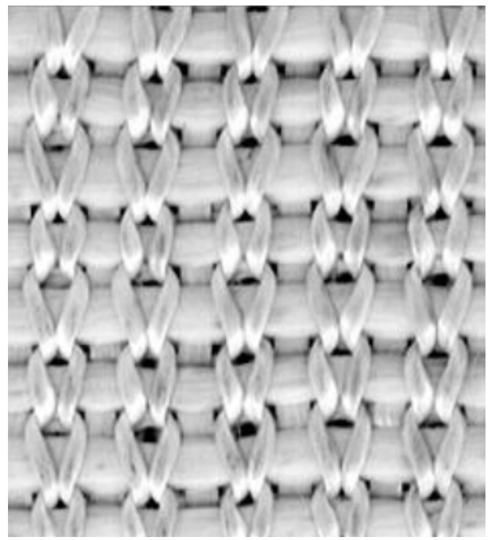


NCF for automotive manufacture

3D textile composites - Knitting

- Dry NCF preform is structural stable, easy for handling.
- NCF preforms have good drapability, which has advantage in produce complex 2D shape without fibre crimp or overlap.





(Side view of NCF manufacture and weft knitted NCF (C. Cherif, 2013)

Examples of 3D textile composites

- **Lamborghini Gallardo Spyder**
  - UD and biaxial NCF.
  - 5 kg reduction and less quantity of parts (from 9 to 2).
- **BMW i3**
  - NCF composite for passenger compartment.
  - Totally 350 kg reduction.
- **Lexus LFA**
  - Braided CFRP A-pillar and 3D woven composite crash box.
- **3D-LightTrans project (Bentley)**
  - Saving 70% time and 45% cost in manufacture in comparison with conventional composite fabrication (estimated result).

Conclusion

- FRP composites have shown the potential to reduce vehicle weight.
- Producing 3D textile composites can be highly automated and required less manually work.
- However, fabrication time could be long (3D knitting and weaving).
- Manufacture costs are relatively expensive to commercial market.

End

(Thank you for your attention)