Rapid development now needed to improve composites fire behaviour in the transport and energy industries

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The composites industry has made steady progress towards meeting fire-related demands, while achieving lightweight structures.

We have now entered a period of change, driven by environmental issues, and important new applications for composites.

Some examples will be discussed.

We will, briefly, look at:

- Issues concerned with fire behaviour
- Massive improvements in manufacturing technology
- Demands associated with lithium ion batteries in cars and aircraft
- New resin systems, including 'phenolic-like' resins, such as benzoxazines
- Composite fire protection

Issues concerned with fire behaviour of composites

FIRE REACTION AND FIRE RESISTANCE

FIRE REACTION

Start-up and progress of fire

- Oxygen index
- Combustibility
- Time-to-ignition
- Surface spread of flame
- Peak heat release
- Average heat release
- Single burning item test

Human survivability

- Smoke generation
- Toxicity index

Small-scale, low cost tests

FIRE RESISTANCE

Mechanical integrity
Heat transmission

- Pool fire tests
- Burner tests
- Furnace tests
- Jet-fire tests

Large-scale, expensive tests

FIRE REACTION

Start-up and progress of fire	Time-to-ignition Peak heat release Average heat release
Human survivability	Smoke generation Toxicity index

Small-scale, low cost tests, typically cone calorimeter or other oxygen consumption calorimetry, such as the room corner test

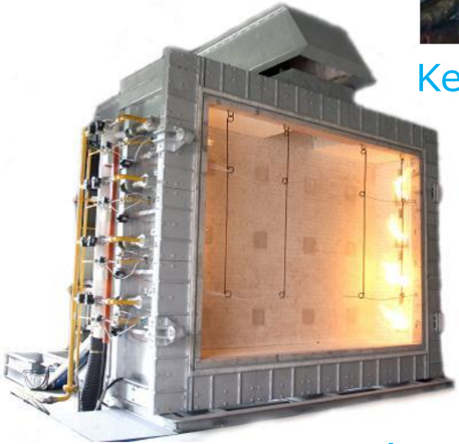
Larger scale, more expensive tests

FIRE RESISTANCE

Pool fire tests
Burner tests
Furnace tests
Jet-fire tests

Kerosene burner (aerospace)

Medium-scale jet-fire (oil & gas)



Furnace test (structures)

Large-scale jet-fire (oil & gas)

Useful information source:

FIRE PERFORMANCE OF FIBRE-REINFORCED POLYMER COMPOSITES

A Good Practice Guide

Composites UK Trade Association

Web-site

Improvements in manufacturing technology

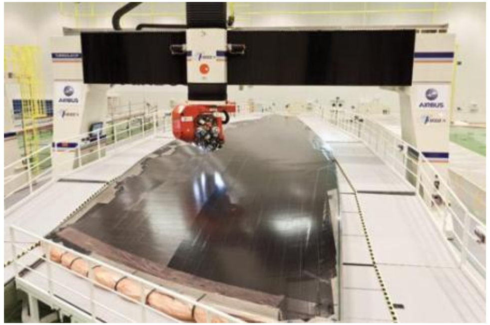
For high volume manufacturing, composites technology has lacked credibility because of slow speed and the multitude of different manufacturing processes

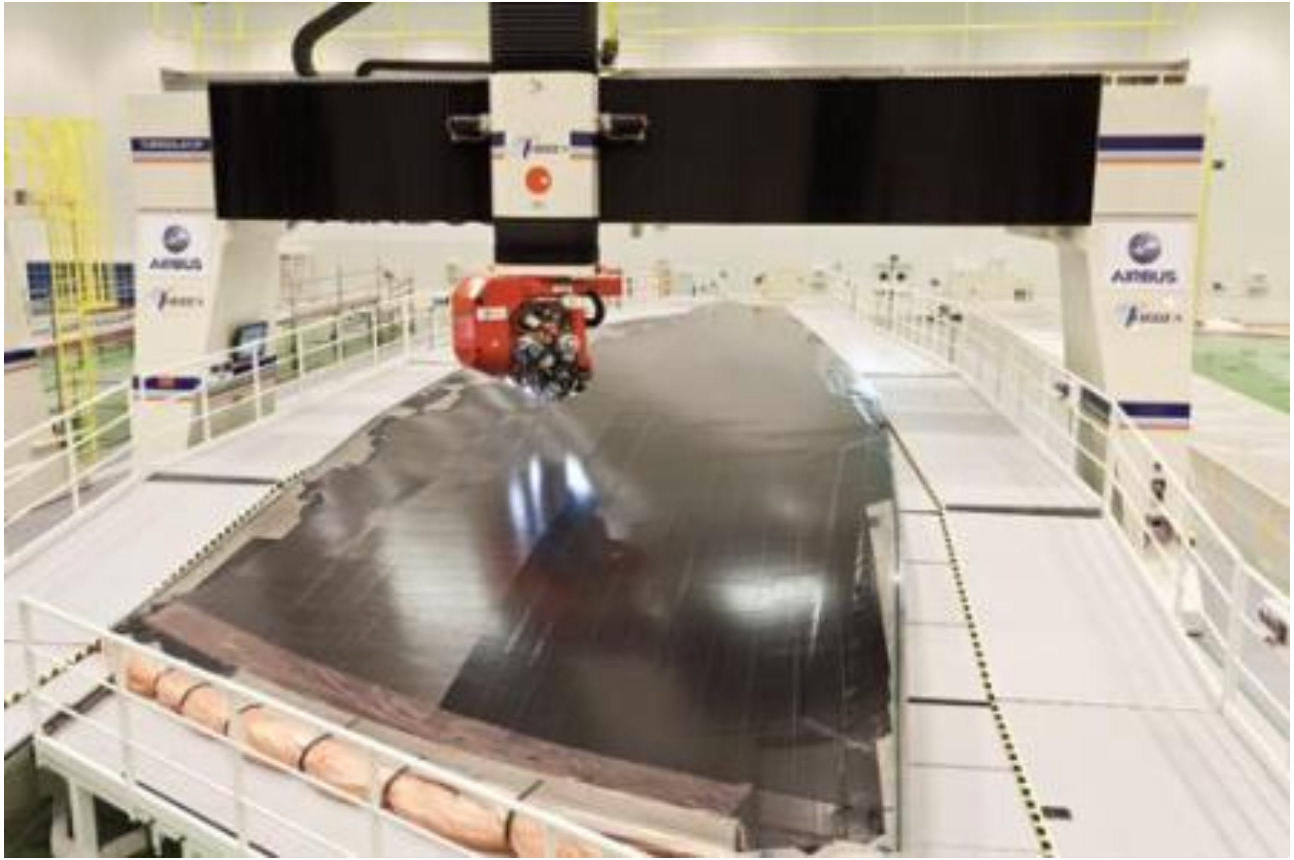
This has changed- the range of processes has become focused on three principal technologies:

Resin infusion (liquid systems)
Automated fibre placement (thermoset and thermoplastic prepreg)
Press moulding (thermoplastic)

Automated Fibre Placement (AFP) pre-dated the more recent technologies for ‘additive manufacturing’.

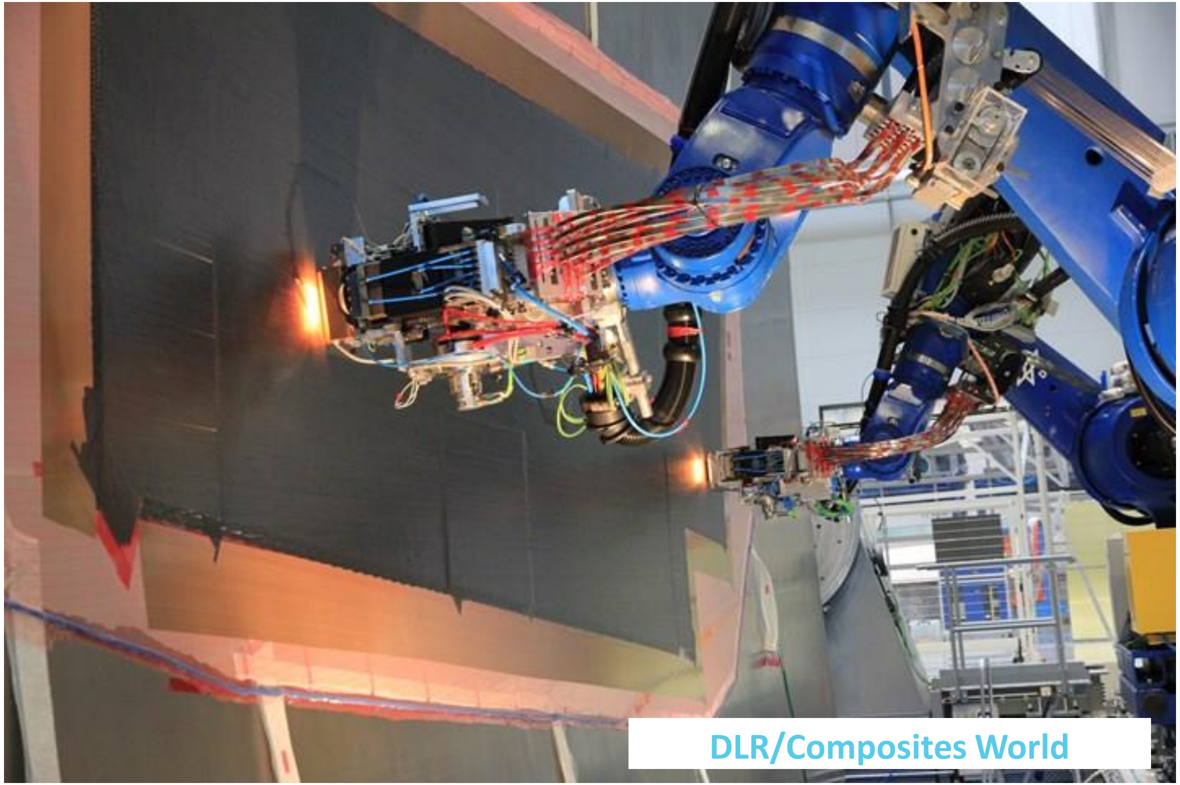
To achieve the lay-down speed and accuracy needed for the Airbus A350 and the Boeing Dreamliner required a revolution in the manufacturing technology. This was quietly achieved.




AIRBUS
AIRBUS

New developments-

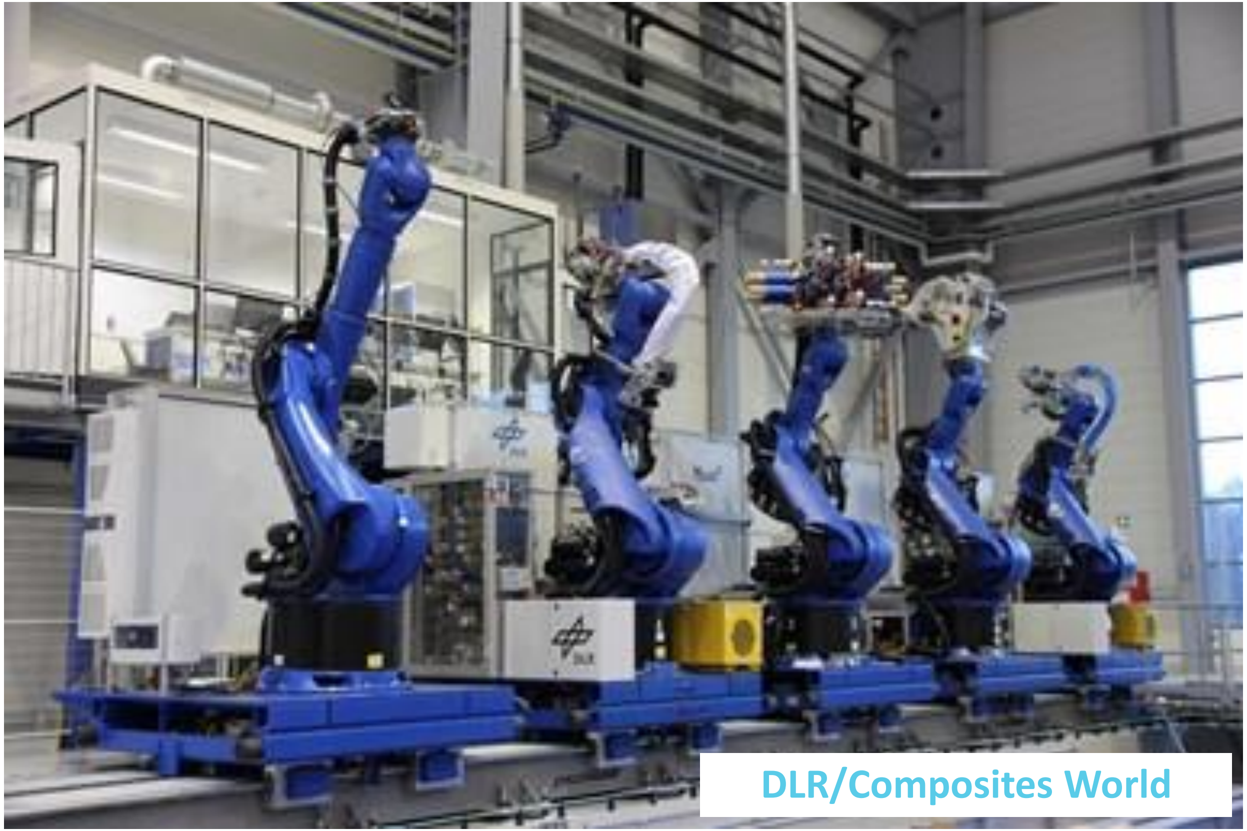
Vertical tooling with moveable robot



DLR/Composites World

New developments-

Multiple moveable robots



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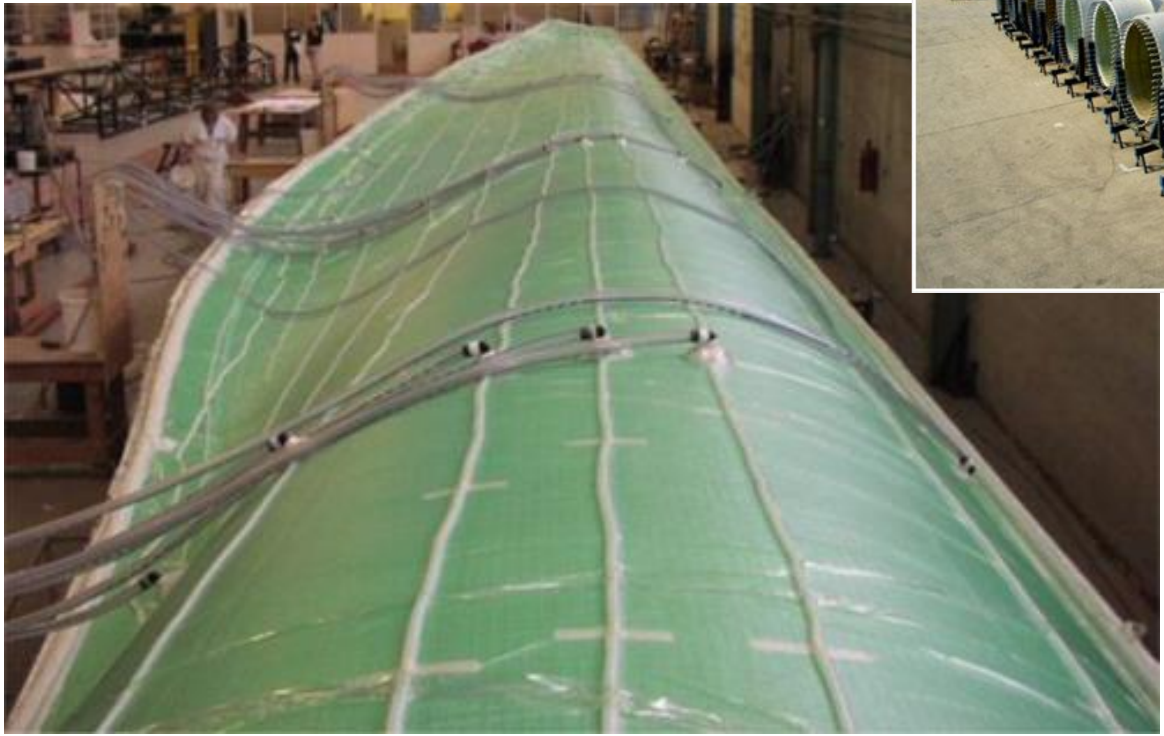
Improvements are also taking place in infusion technology for large components- driven by the wind industry



Lithium ion batteries in cars and aircraft

Ethiopean Airlines Dreamliner

The aircraft was repaired

Photo 3- Venting of the electrolyte from a battery exposed to fire.

General Civil Aviation Authority of the UAE

Battery box containing Li-ion cells, manufactured with PS200 prepreg, after a full thermal runaway 15-minute test. Internal temperature 1100°C, external face temperature 200°C. Photo courtesy of SHD Composite Materials Ltd.

Composite battery boxes

There are opportunities for composite battery protection enclosures

The composites industry needs to take the opportunities related to development of electric cars

See work of Leif Asp (Chalmers)
and
Dan Zenkert (KTH)

New resin systems

Phenolic resins: favourite for smoke and toxicity but difficult to process because of water evolution.

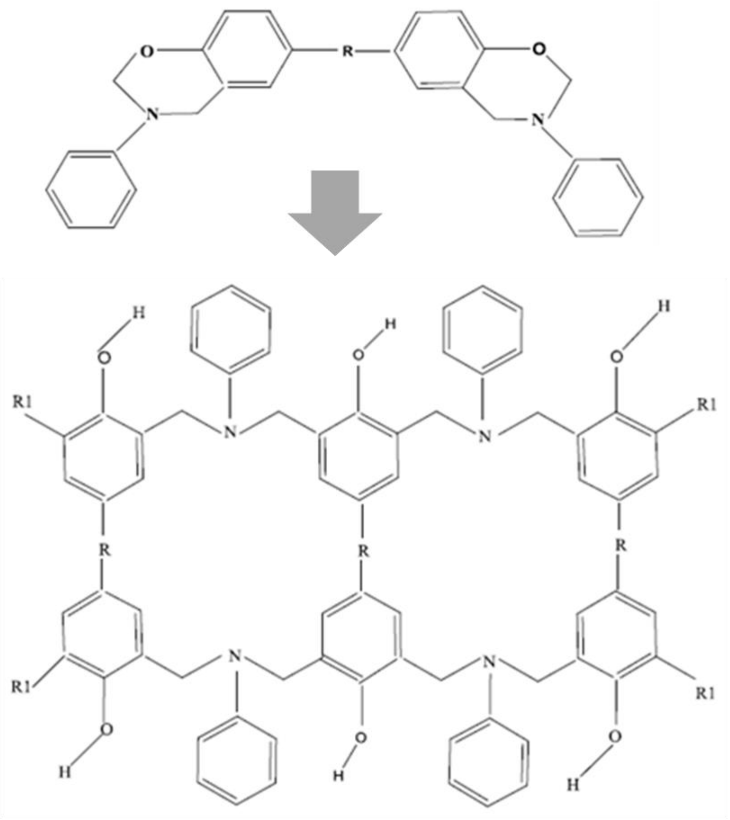
The chemistry didn't really change much in 30 years.

This has changed: benzoxazine resins process easily, without a condensation product. They have all the other advantages of phenolics- and they are tougher.

Benzoxazine

Benzoxazines cure (without by-product) to form a densely packed aromatic network.

They can be blended to form alloys with epoxy or phenolic



D. Roy. Edinburgh University

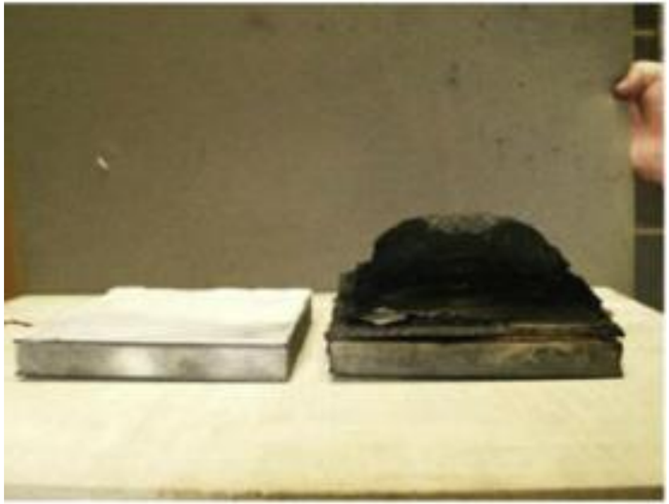
Henkel, Huntsman

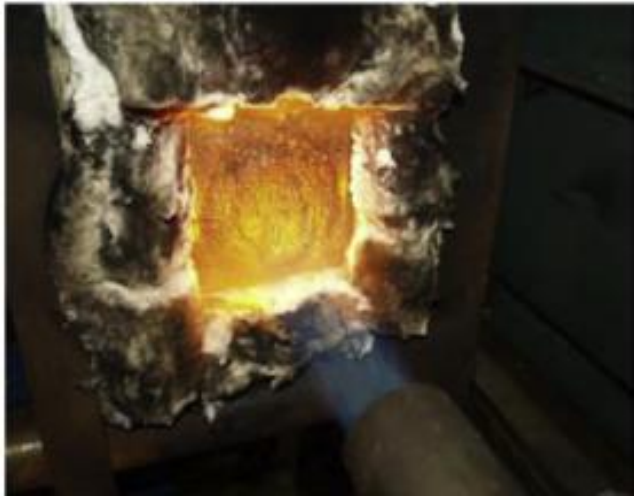
Composite fire protection

Glass/epoxy firewater pipe after 1 hour exposure to a medium-scale jet fire

Future Pipe Industries

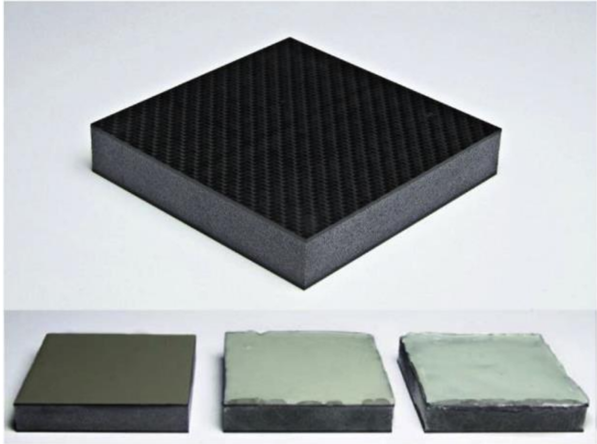
Intumescent coatings for composite fire protection



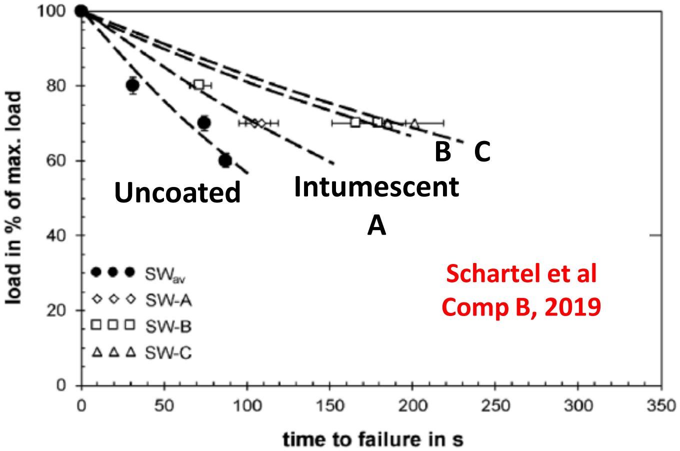


Formula:
Acid source: ammonium polyphosphate
Carbon source: pentaerythritol
Spumifiant: melamine
Balance: resin

Sandwich laminate with composite fire protection



1,100 x 700 mm panels
1.35mm carbon/epoxy skins
20mm PMI foam
1.5mm intumescent



Compression test in
200 kW/m^2 gas burner flame

Conclusions

We have discussed some load and fire-related design aspects of composites

This talk has highlighted important areas where rapid change is either occurring or about to occur