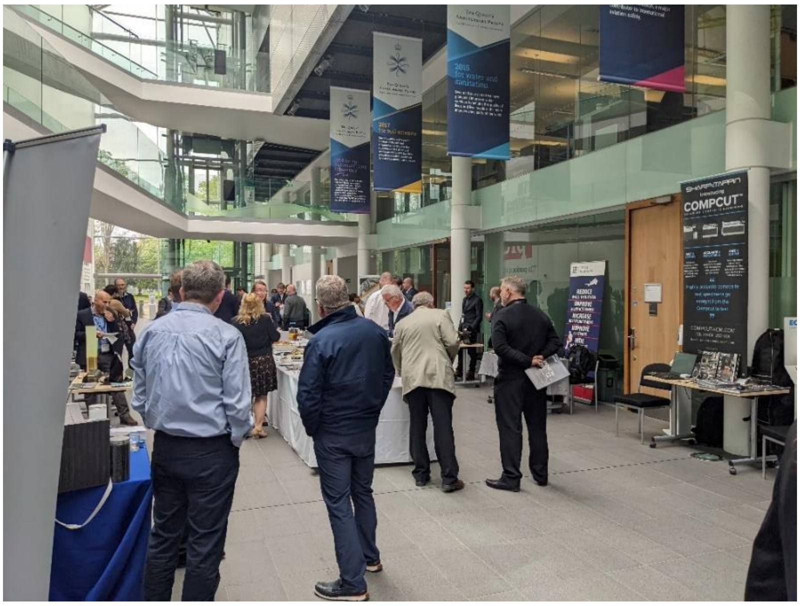
<u>SAMPE UK & IRELAND CHAPTER</u>

Annual Seminar and Tabletop Exhibition, 28th April 2022
Cranfield University

Advanced Materials and Processes in Novel Sustainable Transport

The seminar was a great success with 58 delegates, 10 presentations and 9 exhibitors. Our preferred timing is February, when this seminar was originally planned, and the calendar is relatively quiet with other composites events. The Chapter was determined to hold a physical event for members this year, after the restrictions posed by the Covid virus. Therefore, we put a delay contingency on the planning to April, whilst being mindful that JEC Paris was to be held the following week. Hence, we had competition, and numbers were down on our typical one hundred delegates, but the high quality of the event was unaffected, and feedback was positive.



Special thanks go to our financial sponsors: Cranfield University, Neos International, and the University of Nottingham.

We also acknowledge the important contribution from our exhibitors, the names of which are listed at the end of this report. Finally, our thanks go to the SAMPE Events Team Sub-Committee, headed by Jamie Snudden (Airborne) supported by Sophie Cozien-Cazuc (Far UK).

1. Keynote: Advanced Materials in Sustainable Transport. Alan Banks. Ford and Composites UK

- Alan is Head of Materials at Ford, and Chairman of Composites UK**.** The UK produces 1.4m vehicles per year for home and export combined. Industry's target is to deliver the UK Government's strategy for electrification (and hence CO_2 reduction) and the focus is on lightweight materials.
- Aluminium is vital for lightweight car manufacture and its use is currently inefficient. Ford is now catching up with JLR in the more efficient use of aluminium, but there is a long way to go. Smelting new Al from bauxite uses high energy and produces high levels of CO_2 with the ratio of 20 Tonnes CO_2 per Tonne of Al, based on coal-fired power, as in China. There is 100k tonnes of scrap Al per year, and the automotive industry alone requires 500k T per year.
- Reprocessing scrap Al is much less polluting and is needed to keep pace with demand. Currently, scrap Al is exported for reprocessing, and then re-imported which, due to the double-journey, is highly inefficient and polluting. There is therefore a cost penalty for using recycled Al and the Government must put a levy on high carbon footprint imported materials.
- We need to bring reprocessing onshore in UK. This will have additional benefits of job creation and boost the UK economy, estimated at £2.1bn. In the absence of reprocessing, the footprint from newly smelted Al to service the automotive industry alone, is equivalent to 8.25m tonnes CO_2 per year.
- Carbon fibre is essential for achieving light weight vehicles and the demand will escalate. If all vehicles used CF for light weighting (hypothetical), then 40x the current volume of fibre would be needed! Hydrogen storage tanks is another potential very larger user of CF. Working against the very large energy saving (reduced CO_2) provided by CF in use, is the high energy cost of production. (Elsewhere, it is calculated that the embodied carbon in CF is 30 - 50 kg CO_2 per kg CF, i.e., a ratio of say 40:1, compared with Al at 20:1. See above, and Dowty Propellers presentation, Section 8).
- Possible energy savings in CF production were given as: (i) 0.47T CO_2 /T CF from renewable energy (ii) 2.2T CO_2 compared with coal fired power (iii) 2.4T CO_2 saved with new CF technology from Le Mond. The latter is targeting "carbon-neutral CF production" and has a patented process based on fast oxidation, and a UK plant may come on stream in 2024/25.
- The importance of automotive-grade steel was also highlighted, with electric arc processing replacing blast furnace processing to significantly reduce CO_2 emissions (but the former can only be used for recycling existing scrap "carbon-steel" from the BF process).

- There is a shortage of glass fibre, and recycling is vital, although virgin fibre production persists because it is perceived as a cheap process. (In Q&A it was mentioned that Strathclyde University is working on recycling glass.).

2. The Use of Frictional Tests to Determine Defects in Multi-Layer Composites. Guy Lawrence. The University of Nottingham.

Guy was a winner of the "Young Engineers and Students" competition. He is a 2nd year Ph.D. student. Against the background of a large market increase in demand for fibre reinforced composites for aerospace and wind energy in particular, a better understanding of inter-ply properties is required, which is often composites' "weakest link."

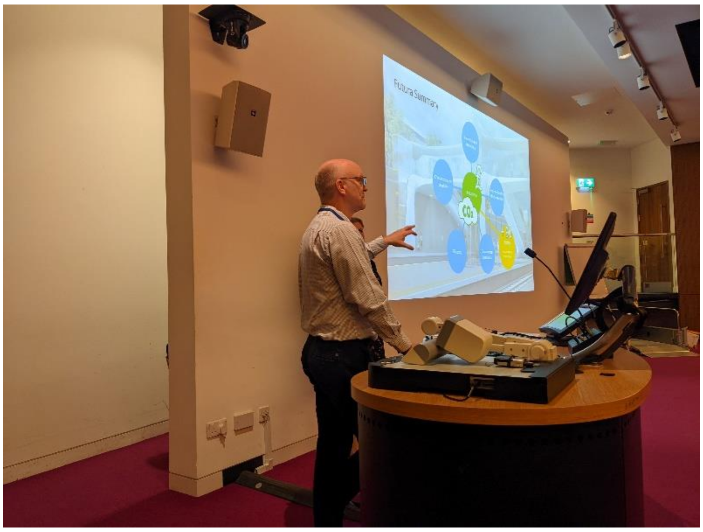
- A Double Diaphragm Forming process (DDF) was used for automated pre-forming. Illustrations of a seat back were shown of how defects can occur when a 2D laminate is shaped into a 3D form. Three types of in-plane defects were shown caused by bridging, wrinkling and fibre buckling. Analysis involves isolating these planar characteristics and measuring their frictional properties. Testing is aimed at both predicting and remedying the defects. Coefficient of friction is normally measured by the Sled Test, but a new test method has been devised – "the overlap friction test" – which measures the force needed to slip / slide the in-plane layers.
- From the load vs. extension curve, measurements are converted to friction coefficient vs. extension. Static Friction rises at first to a peak, and then reduces to a plateau region as Sliding Friction takes effect. This curve characterises different layups. High inter-ply friction causes defects, especially in automated processes. Ways to modify friction were examined: using liquid resin, powder binders, and inter-layer veils. The importance friction plays in defect formation and failure mode depends on the working load, and the fibre orientation. A useful and much better understanding of the role of friction in defect formation has been achieved.

3. Futura Rail Bridge Project. Matt Hocking. NCC

- The origin of the project is the need of Network Rail to replace 2300 footbridges over the next 30 years. Partners in the project are: NCC, COWI (structural engineers), Marks Barfield (architects), Neos International, and DFS Composites. The aim is to design, build, and install one prototype bridge by 2024.
- Using current conventional materials, it would take 120 years to make 2300 bridges! At a current cost of £4m per bridge, the cost would be £10bn. The problem is that most

footbridges are not the same, they are bespoke and must fit the geometry of the individual station and track layout. Fibre reinforced plastics offer huge advantages:

i. light weight – 67% weight of steel; 14% weight of concrete.
ii. non-conductive.
iii. long life – 120 years is required.
iv. low embodied energy (CO_2) – 41% compared with steel, 43% compared with concrete.
v. ease of installation – fitting in one day is required.
vi. lower cost – a minimum 50% cost reduction is required.



- A catalogue of bridge variants has been made and the different geometries have been consolidated into a minimum number of modular designs, for example, specifying horizontal span and pillar height. A minimum stiffness deflection must be achieved - minimum 50mm deflection for a 12m span. Various composite constructions have been selected for different sub-components, including glass fibre / carbon fibre, unidirectional, quasi-isotropic, cross-ply, and low FST resin. Current work is focused on FST and durability testing.

4. VLR Track: A Novel Track System to enable Sustainable and Affordable LRT Implementation. Chris Micaleff. WMG

- The project is designated CVLR – "Coventry Vehicle Lightweight Railways" and the selected vehicle is the tram. The tram was selected as the greenest transport system, to reduce local emissions and to regenerate the city. The light weight is achieved by a combination of the materials used in the cabin structure, the battery power pack, and the design of the track.
- Interestingly, the absence of vehicle tyres significantly reduces urban pollution. It is estimated that tyre wear contributes over 300k tonnes of toxic particulates per year in USA and Europe. The cost of extending tramlines in, for example Birmingham and Manchester, is £70m per km. An estimate for extending a tram network in Coventry using conventional methods, was £100m per km. This project has a cost requirement of just £10m per km maximum.
- The track cost for fabrication and laying is typically £2m per km, so a radical re-design is necessary. Rail height and rail foundations are critical. The CVLR new design uses a shallow rail height and stronger but simplified foundations. Ultra-High-Performance Concrete (UHPC), reduces the slab height to just 10cm, greatly reducing the complexity and cost of the earthworks. New fasteners and caps are designed to join the rails.
- CVLR's route to market is to complete a 3km demonstration track in Coventry by 2023, with a tram car capacity of twenty people. If successful, Government approval is needed by Act of Parliament to install the complete tram network in the city.

5. Making Automotive Composites Circular. Jen Hill. B M Longworth

- The company is family run and was founded 46 years ago. Formerly a component cleaning company using mainly ultrasonics technology, BML is now more correctly defined as an innovation company. Some years ago, they designed and installed new technology based on super-heated dry steam, "DEECOMP." All materials can be cleaned in this manner, including plastics and composites. It became apparent that the technology was more than a cleaning process when it was realised that the materials removed were not waste, but valuable.
- The core speciality of the DEECOMP process is the decompression phase which causes what was described as a "molecular explosion." Importantly, composites can be separated into fibre and resin, both of which are reusable. Carbon and glass fibres can be processed, and surprisingly, thermoset resins like epoxy, can be recovered, and be re-used, certainly for paint additives, and other lower grade applications, for which the ecological benefit is clear compared with new oil-based production of raw materials.
- The recovered materials have very much the appearance of virgin material but should be considered as very valuable alternative materials. The recovered fibres behave and process similar to virgin fibres because the fibre is basically just cleaned, and no (resin) pyrolysis is involved. An illustration was shown of a filament wound hydrogen tank, the carbon fibre of which had been DEECOMP-processed, the fibre unwound onto spools, ready for rewinding. Some discussion took place regarding whether the fibre size (processing aid) remained in place, or indeed whether the process can be adaptable in this respect – remove / retain.
- The future of B M Longworth is not as "recyclers"; they will seek partners with composite fabricators with a large waste problem and sell technology. DEECOMP plant comes in sizes from tabletop to 3000 litres capacity.

6. Leveraging Biomimicry to Decrease Material Usage and Enhance Performance for Green Composites. Lorenzo Mencattelli. Helicoid Industries.

- Man-made composites achieve high strength, high stiffness and low density, but suffer from poor impact tolerance. Shellfish and insect cases achieve tensile strength 10x that of their constituent parts and have by "design" high resistance to impact and crushing. These "helicoid" structures have chitin protein fibres aligned in consecutive layers, progressively twisted, at a shallow angle to the through-thickness axis.
- Helicoid Industries are partners with sixteen universities in a $12m project to understand helicoid structures and adapt the knowledge to fabricated composites. A quasi-isotropic composite was compared with a helicoid layup, using the same fibre and resin systems. The latter had significantly lower impact damage and achieved the same load bearing at lower weight, offering savings in costly raw materials. The helicoid structure showed initial damage at +21% load and 5mm extension but continued to bear load to 20mm extension. Overall, the energy absorption was +57% compared with the QI layup.
- It is expected that these helicoid structures could be adapted for AFP, although it may require up to a minimum of 10 layers to achieve the effect.
- The second part of the presentation concerned hybrid structures using organic fibres. Glass fibre composites were compared with flax / glass hybrids. A hybrid structure of 50% / 50% gave +25% tensile strength compared with 100% glass fibres.
- Potential applications for both of the above novel composites include aerospace (nacelle and flaps), (although qualification issues were not discussed here), battery enclosures, H_2 storage tanks, and leading edge rotor blades for wind and rain erosion.

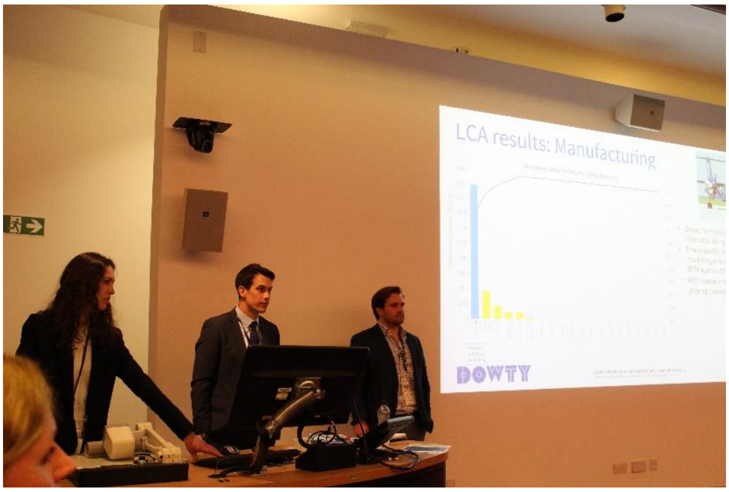
7. Materials and Structures for eVTOL Aircraft. Will Tulloch. Vertical Aerospace.

- Depending on the flight range, eVTOL aircraft are targeted at three markets: airport transit (25 to 50 miles), inter-city, and inter-island /tourism (60 – 100 miles). Vertical Aerospace was founded in 2016, and the first flight of the prototype VA-X1 was in 2018. Vertical Aerospace was then floated on the NY stock exchange in 2021.
- Work is now focused on the VA-X4, specification: four passengers, 100 miles range minimum, fully battery-powered, vertical T/O and landing, maximum use of composite materials. Staff numbers have grown from 70 to 200 to deliver certification by end 2024 and achieve growth to a build rate of 1500 aircraft per year capability.
- Challenges are weight, cost, loads, and build rate.
  (i) Weight reduction is achieved by maximum utilisation of composites: fibre placement, 3D printing, thermoplastic resins.

(ii) Cost is addressed by low-cost materials, automation, sustainability (renewable energy and re-cycling).
(iii) Rate is addressed by design for manufacture, latest manufacturing processes, and collaborations with manufacturers.

- Short-term needs are availability of parts, both metal and CFRP, and staff.

8. New Sustainable Propulsion Technologies. James Trevarthen and Emma Bryan. GE Dowty Propellers.



- The main challenge in aerospace is to meet zero emissions by 2050. There are many means of minimising CO_2 pollution:
(i) sustainable aviation fuel (SAF)
(ii) hydrogen direct burn
(iii) hydrogen fuel cell
(iv) hybrid and electric power packs.
There is a demand for low noise propellers, which is achieved by greater energy efficiency, and hence lower fuel consumption. High usage of composites achieves light weighting and enables complex structures. Additive manufacturing enables a further 50% reduction in component weight, more complex structures and reduced scrap.
- Dowty is making a detailed study of Life Cycle Analysis regarding the sustainability of both parts and processes. LCA is used to drive R&D, in order to optimise design. Embodied carbon (per kg CO_2) has been measured in each stage of the blade manufacturing process.
The highest CO_2 emission is embodied in procured raw materials (especially carbon fibre) at 2700 per kg CO_2. Next highest (at approximately 75% of the raw materials) is for materials used specifically in the blade-making process per se. Third and equal, at approximately 50% of the raw materials emissions, are both the transportation and manufacturing process energy. Finally, re-cycling offers a negative CO_2 emissions profile.
- The highest embodied carbon material in the raw materials list is carbon fibre at 2250 kg CO_2 per blade assembly (6 CF blades plus metal fittings). The blades comprise 60% of the embodied carbon in the complete propeller. This corresponds to an embedded carbon ratio of approximately 45:1 (45 kg CO_2 emitted per kg CF produced). It was noted that there is a large range in quoted embodied energies for CF, 183-286 MJ/kg (depending on process efficiency and CF type). RTM is also high in embodied carbon, but better than that offered by other prepreg moulding processes.
- For volume production, automated composite manufacture is vital and a process beyond standard AFP is required. The aim is to reduce carbon waste by greater than 50%. The next challenge is to integrate the processes into a single line, and to fully introduce automated inspection.

9. Opportunities for Tooling in the UK. Beene M'Membe. ATI

- The purpose of ATI (Aerospace Technology Institute) is to assist the development of the UK aerospace industry. It endeavours to be financially self-sufficient by providing contract services, and then re-distributing the revenue received to support emerging ventures. ATI received less than £150k in direct (Government??) grants and distributed £129m in total to a list of 235 SME's.
- Amongst other activities, ATI organises Webinar networking meetings, bringing together clients and suppliers where there is technological synergy, and introducing companies who may benefit from formal working partnerships. The next webinar on joining is on 10th May 2022. ATI also publishes cutting edge periodicals, "Accelerating Ambition", the latest 2022 edition on the topical subject of "Destination Zero."
- ATI admit that tooling is not the most "glamorous" of subjects, but it is an important and neglected field. The aim is to increase the UK capability for tooling R&D, and to bring a supplier base here, as opposed to mainly overseas. Some challenges for improving UK tooling expertise are:
  (i) reducing lead time (ii) costs (iii) early engagement with suppliers (iv) refining business terms to win contracts (v) understanding the requirements for tooling interactions with factories (vi) support to develop innovation. ATI heavily funds developments in the latter area.
- ATI is preparing a Tooling Directory of suppliers and facilities. Categories include type of tooling <10m and >10m, layup, auto cure, oven cure, press cure. Supplier availability is categorised as Green > 10 suppliers, Amber 5-10 suppliers, Red < 5 suppliers.
- Priorities for tooling are: (i) the infrastructure and technology to enable large scale tooling developments (ii) advanced materials tooling (iii) multi-functional energy efficient tooling (iv) tooling for H_2 tanks (v) advanced modelling and simulation capability for tooling. ATI funds post-TRL6 innovation.
- The road map for tooling is (i) right first time (ii) reduce costs and lead time (iii) digital integration (iv) reducing environmental impact.

10. Low Power Curing of composites using Direct Electric Cure. Matthew Collinson. AMRC.

- The energy embedded in various raw materials was compared:

Material	MJ/kg
Epoxy	76-80
Polypropylene	72-112
Carbon fibre	183-228
Glass	13-32
RTM process	12

- Lower energy is possible if CF can be replaced with bio-fibres, and epoxies can be replaced with thermoplastics or bio-resins. RTM is significantly less energy intensive than prepreg moulding.
- The NASTRO project has sixteen partners with AMRC as lead partner. Composites are made by Direct Electric Heating. In DEH, copper electrodes are attached at the ends of the layup and make contact with the conducting carbon fibres. An electric current is passed through the carbon fibre to generate heat, and a vacuum is applied. The insulating behaviour of the epoxy resin causes hot spots, where the current takes the path of least resistance, and this results in a degree of non-uniform cure. A plain weave CF fabric was used to replicate a typical commercial fabrication. Satisfactory results are obtained using a UD layup. It may be possible to use sacrificial UD layers on the faces to gain this benefit, even when using a bulk fabric reinforcement. The energy benefit is shown below:

Cure	Energy (kWhr)
DEC self-cure	0.38
small oven	8.88
large oven	420

- Future work includes (i) scale up from lab to industrial (ii) complex components (iii) smaller re-usable electrodes (iv) zoned heating (v) better insulation (vi) low conductivity fibre / resin interface. Finally, an interesting video was shown of a large CFRP component during a de-icing process, using direct electric heating.

Tabletop Exhibitors

Airborne	**Bindatex**	**SHD Composites Materials**
Dia-Stron	**Gearing Scientific**	**Surface Generation**
Gen2Carbon	**Sharp and Tappin**	**Tygavac**