SAMPE UK and Ireland Chapter
Annual Seminar and Table Top Exhibition
7th February 2018
University of Nottingham
Intelligent Composites Design and Manufacture

The seminar comprised 9 presentations and was attended by 100 delegates including 18 exhibitors. Thanks are due to our three sponsors – Gearing Scientific and JR Technology in conjunction with DolphiTech. We acknowledge also the generous support of the University of Nottingham in whose new Advanced Manufacturing Building the event was held. We also thank Trevor Cook and David Carlton of SAMPE UKIC for organisation.

1. **Keynote Presentation. Resin Infusion Material Developments for Integrated Structures. Sebastien Greber. Solvay**.

- Cytec was acquired by Solvay in 2015. Their latest aerospace developments were presented in relation to dedicated resin infusion (RI) technologies. The aircraft market is large, for example Next Generation Single Aisle output is approximately 60 a/c per month, and increasing use of RI is forecast, from less than 5% in 2017 to more than 25% in 2035, including thermoplastics.
- Bombardier C-series wing utilises Cycom 890. Highly toughened resins such as PR520 are well suited to small structures requiring high toughness, however less suited to large scale resin infusion due to process-ability.
- RI material handling requirements for spars, wing skins and stringers are: high deposition rate, low bulk and fibre preform permeability. Properties required are high strength and stiffness, and high compression after impact (CAI), particularly for skins. Solvay offer a number of fibre and resin options.
- Prism EP2400 is a very high toughness epoxy with good flow and generous 8-10 hrs infusion time. TX1100 is a dry fibre tape for AFP, with good weft stability, permeability and excellent physical and mechanical properties. IMS65 carbon fibre is used for stiffness and optimum impact performance. The fibre tape used a special binder, Cycom 7720, effective in the forming and (if required) removal of individual plies.
- Prism 2200 is an advanced NCF broad good for high deposition rates, while ensuring low bulk and high physical and mechanical properties.
- The MS21 wing and spar were presented as case studies (MS21 is a Russian a/c like the Airbus A320). TX1100 fibre / EP2400 resin is used, processed by AFP. For the MS21 spar, the low bulk and high stability of TX1100 enables AFP lay-up on the male tool, and cure in the female mould.

- RI enables low production cost hence high rate, high structural integrity with fewer assembly holes, lower capital and supply chain costs (no autoclave) and shorter time to production. The required textiles can be expensive but help to reduce overall part cost.

2. **Developments in Composite Drape Simulation by the Incorporation of AI Techniques. Shashitha Kularatna / Carwyn Ward. University of Bristol.**

- Hand lay-up is still the main route for making complex structures. AFP often needs some hand lay-up assistance to achieve non-wrinkling of fibre reinforcements, particularly with woven fabrics.
- A video showed two simultaneous hand lay-ups of the same part with two experienced operators, and distinctly different procedures were used to achieve the same end-result.
- Using the film it is possible to identify 8 basically different procedures using the hands to achieve drape and conformability. However there are many more constituent actions within these procedures, many based on the human learning process of trial and error.
- A computational technique was described which analysed these hand movements and modelled the human learning process. This is termed "reinforcement learning" and is based on trial, error, and accept / discard criteria. The computer identified 58 individual actions and is programmed to act as an AI agent with built-in system "rewards and penalties." The computer is programmed to act "SMART" in an iteration of learning from errors, improving, and finally achieving the end-result.
- A key output is the optimised sequence of actions to achieve both the best quality and fastest result. An animated example was shown of the efficient conformable draping of an out-of-plane 2-D reinforcement.

3. **From Scrap to Structure: Changing the Perception of Waste. Ross Key. Solvay.**

- Solvay has a mission for green processes, targeting 50% sustainable solutions and a 20% reduction in carbon waste. As an industry standard, CFRP utilisation is typically 65-75%. This is a "lost" cost to the Solvay business and generates up to 1 tonne pa of hazardous waste with additional costs of disposal. Solvay target 100% utilisation and a key innovation here is in RMC – **Recyclate Moulding Compound**.
- The RMC process uses a special extruder which feeds in uncured prepreg and converts continuous fibre to short fibres of variable length. Solvay has developed special prepreg resins to be compatible with the RMC process, for example, viscosity retention after re-processing.
- The output is BMC (e.g. for cavity filling) and SMC for more sophisticated hot compression moulded composite end-uses. Mechanical performance is better than glass fibre SMC but typically slightly lower in flexural performance than commercial carbon fibre SMC. However compression and tensile properties are at least the equivalent of CF/SMC, despite the latter having longer fibres. All properties can be enhanced by optimising resin formulation and processing conditions.
- An automotive part made with RMC was shown which is 40% lighter than aluminium and has a higher mechanical performance.

4. **PROSEL: An Online Design Tool for High Performance Composites Materials and Process Selection. Andrew Mills. Cranfield University.**

- Whilst data for metals is well established, the effective use of composite materials is still sometimes considered a black art, despite a 50-years history with prepreg tapes and woven fabrics. Knowledge often lies in pockets of individual expertise with no central data base. Also, new products and processes are constantly being added to the manufacturing bank. Data access is important for both optimum use and for training new engineers.
- There are many aspects to a new component which must be considered: shape limitations, reinforcement options depending on performance requirements, production rate (not necessarily as fast as possible), structural requirements, others.
- Andrew accessed the data base on screen and gave a case study example of what needs to be considered for making a Jaguar car roof. Each constituent in the supply chain is highlighted and opens a huge list of suppliers and products. For example, tool options reveal a list of at least 15 types. Similar lists are established on the data base for fabrics, fibres, resins, process types, and equipment.
- The programme enables a **combination** of requirements to be put together, and then a relatively short list of options is revealed. The summary gives supplier name, process type, product, basic properties, weight, cost, labour cost, and finally estimated total cost of use.
- This is a unique world-wide resource. The data base is detailed and up to date; it is impartial and rational and is frequently updated. The data base does not yet include international standards / qualifications, but will in due course. Thanks were given to BI-AMSCI, Axillium and Solvay for funding, and to all data contributors.
- http://www.prosel.co.uk

5. **Future-Proofing UK Composite Manufacturing. Amit Visrolia. NCC**

- NCC is part of the HVM Catapult project and focuses effort on TR 4/5/6. Customer needs are identified as increased rate and increased reproducibility, to be achieved simultaneously. Composite trends include: larger volume, larger parts and higher complexity.
- The technical challenge is the inherent variability in materials and processes. Processes are often treated as black art and are just repeated; they are not intelligently scrutinised and modified accordingly. Different processes have inherent different relationships of Cost / Reproducibility / Performance, eg hand lay-up, AFP, ATP, RTM, braiding.
- Processes are highly integrated and NCC has developed a digital representation of the manufacturing process, known as "dig-twinning." Artificial Intelligence (AI) is used to make decisions automatically. The technology is referred to as CLAMPS – Computer Learning in Automated Manufacturing Processes.
- RTM was highlighted as an example of an often poorly controlled process, giving incomplete infusion with dry spots or air entrapment. There are controlled variables (eg preform dimensions, injection pressure, volumetric flow), and uncontrolled variables (eg input material weight, compaction / wrinkling, resin age, ambient temperature).

- CLAMPS begins with the digital processing of known inputs to known outcomes. For example, time of valve opening and position of resin input valves – the output is, do we observe dry spots or not? Is this process fast or slow? Using this stored information and AI learning ability, the programme then converts real inputs to predicted outcomes.
- The technique shows early success and further refinements in prediction include additional input variables and the optimisation of sensor positions. NCC has confidence that this techniques will enable the manufacture of complex components at higher speeds with minimal variability.

6. **<u>Developing the Floor-Pan for the BMW i5. Antony Dodworth. Bright Lite Structures.</u>**

- Earlier automotive composite work at BLS (Bright Lite Structures) was summarised. The first success came with the BMW 5 Series bonnet development. At just 7.2 kg the bonnet is 10 kg lighter than the aluminium equivalent, and stronger. Design is paramount in achieving simplified structures with fewer sub-components, and hence reduced assembly costs, together with the use of affordable materials.
- The 1-piece chassis for the Zenos racing car involves simple, low cost tongue and groove jointing with adhesive pumped down the cavity, together with recycled CF from SGL plus a little NCF, and a special spray-head delivering 7 components including 2 PU resins, epoxy, pigments and mould release agent. The sandwich is compression moulded on a Huntsman PU core with an 8- minutes cure time. Impact testing was considered to be "irrelevant" after a real-life crash at 110 mph resulted in no damage to the chassis and no injury to the driver!
- The BMW i5 comes in battery format and hydrogen fuel cell format. Both designs retain an aluminium structure at both ends supported by the composite floor-pan. The front bulkhead is made from blended PU and epoxy resin and the short fibre recycled CF (ex-SGL) enables a 3-D shape to be made from a flat panel, due to fibre slip. The bulkhead weighs just 6.2kg, and thousands have been made to date
- The floor-pan weighs 15kg compared with aluminium at 51kg. Crash test results are excellent with no delamination between core and outer panel. The target for the BMW i5 H-cell chassis is 120kg and 123kg has been successfully achieved. Approximately 800 floor-pans have been made to date.
- Other current non-automotive applications include aircraft seats using a pre-shaped core and a special spray-head to deliver a high viscosity resin.

7. **<u>The EPSRC Future Composites Research Hub. Andy Long. University of Nottingham.</u>**

- EPSRC (Engineering and Physical Sciences Research Council) is looking at the mid- to long-term future requirements of the composites industry and the gaps which need important and imminent attention. The forecast growth in composites is large:

  2015 £2bn
  2020 4.5bn
  2030 £6-12bn

  We need to address the question of whether we can achieve this growth with current materials, processes and labour force.
- The EPSRC Hub addresses TRL1/2/3 issues and comprises a consortium of 10 University partners, of which University of Nottingham and University of Bristol are the leads,

together with 18 industrial partners. The objectives include: (1) achieve a step change in composite manufacture, science, and technology (2) create a pipeline for next generation technologies (3) train more engineers (at least 150 per year are needed), (3) build and grow national and international communities in composites manufacture and design.

- The prime strategy of the hub is (1) to enhance process robustness (2) to develop high rate process technologies for high quality structures. The hub partners specialise in distinct technology areas, eg higher quality preforms (University of Nottingham). At Nottingham, the focus will be on modelling techniques, not merely using old (modified) textile processes. Other partners are examining electrical storage composites and electric sensors in composites, others the 3-D forming of composites from 2-D reinforcements.
- The hub partners by sector are well spread and represented and comprise 23 international institutions across 11 countries. Communications, including travel to locations within the network, are facilitated. Funding sources are (1) £10.3m ESPRC (2) £8.9m Industry commitments (3) £3.5m Institutions. Industry can sponsor dedicated research work of mutual interest, for example:

Sponsor	**PhD**	**EngD**
Location	Uni	Industry (75%)
TRL	1-3	4-6
Cost pa	£18k	£20k
Years	3	4

8. Advanced Automatic Tape Laying with Fibre Steering Capability using Continuous Tow Shearing. Evangelos Zympeloudis. University of Bristol.

- Evangelos was one of the winners of the SAMPE UK & Ireland's Student Seminar in 2017.
- The composites industry uses prepreg materials containing straight fibres, either for u/d or quasi-isotropic lay-up. AFP and ATP processes lay down straight fibres but 2-D curvature is most often required, to produce a curved shoulder for example. Depending on the width of the tape, buckling occurs to a greater or lesser extent, in turn depending on the radius of curvature of the part, and the difference in the required radius of curvature across the width of the tape. At 8mm the problem with fibre placement is small, but at higher widths buckling occurs. However there are cost issues with using narrower tapes.
- A shearing mechanism is needed to allow fibre slip; **intra-tow** shear is beneficial, whereas inter-tow shearing is bad, and results in buckling. A CTS device was explained (continuous tow shearing) to enable tow slippage. The dry fibre tapes can also be made amenable to shear by the inclusion of a fusible weft yarn or a high-slip woven weft yarn for example. However CTS is effective even on prepreg tapes, after a reduction in tack is made to encourage slip. The technique is effective with bending radii from 50mm, right up to 200mm tape width.

9. Augmented Learning for High Dexterity Manufacturing. Dennis Crowley. University of Bristol.

- Composites are difficult to fabricate and hand lay-up operatives learn by "doing" rather than by understanding. Operatives take significant time to acquire the skills needed and the skills base is a significant industrial concern.
- Solid templates showing the sequential shapes and procedures for lay-up are unwieldy and are to the side of the operatives direct vision. Direct laser projection on to the part itself is an improvement but image flashing is distracting. Anaglyph technology projects the template on to a screen which solves some problems. but not others.
- The "LayupRite" solution uses a simple low cost overhead projector to give a direct-on-part image. The latest design iteration gives higher image brightness to aid the operative. Future developments include a finer accuracy of the projected image which is currently around 1mm. The work is funded by the charity UFI which supports vocational training.

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