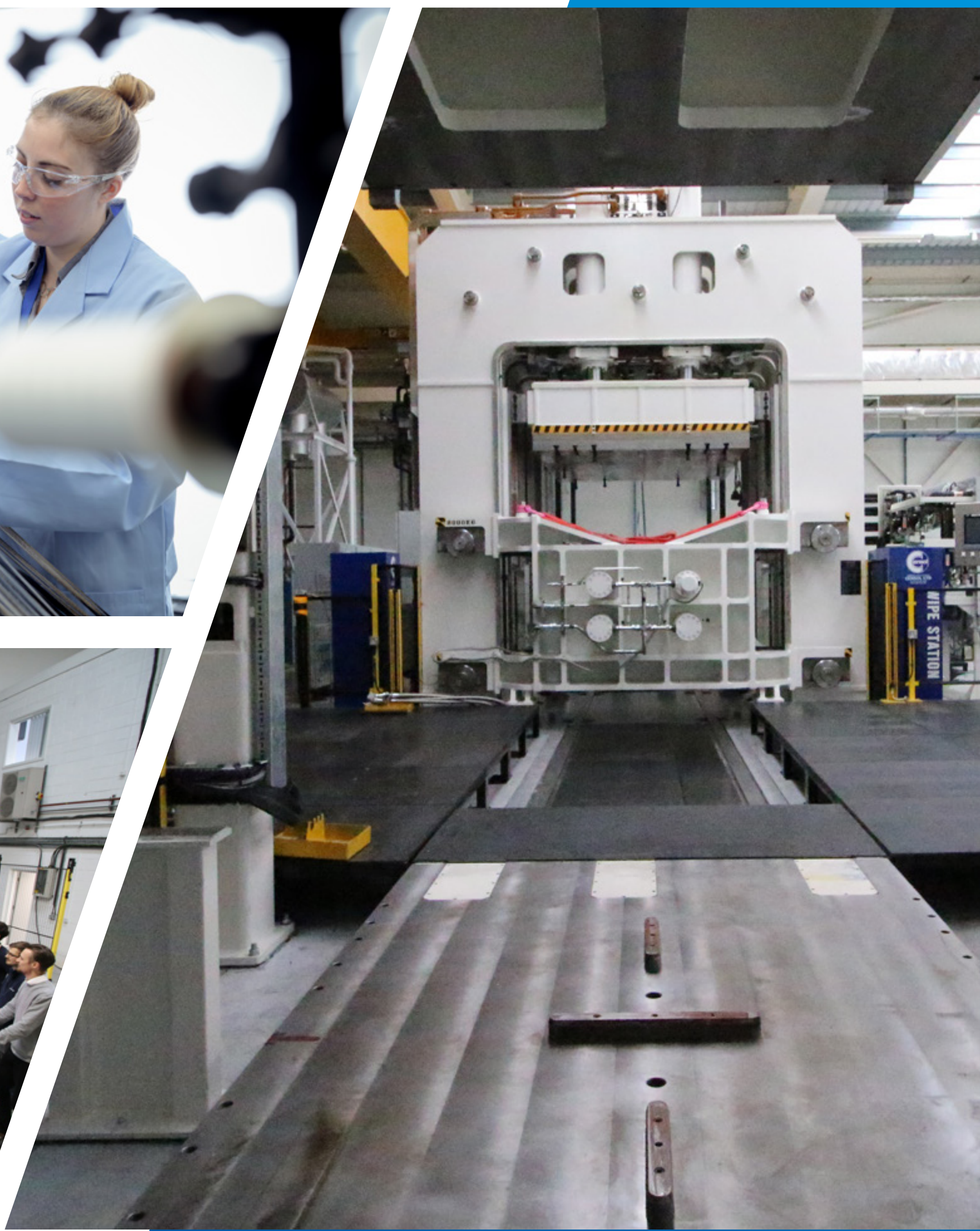
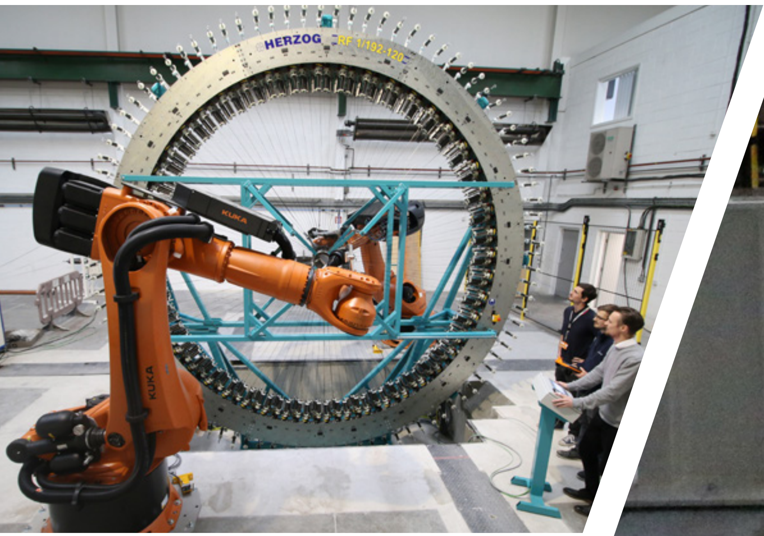
AMRC Composite Centre

Capability directory





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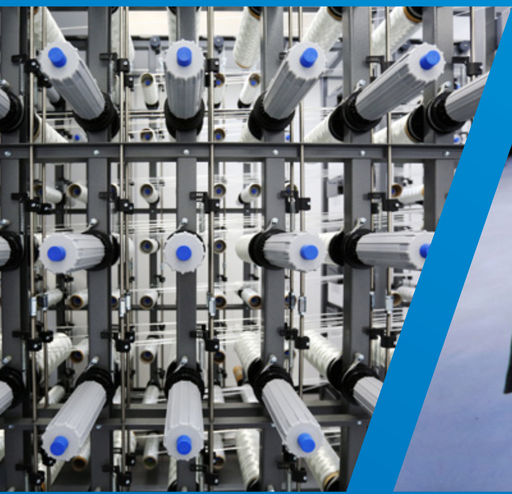


The AMRC Composite Centre extends the AMRC's expertise in metals production into the new generation of carbon fibre composite materials.

The Composite Centre facility includes a general workshop and 900 sq m of high-spec clean rooms. It houses a range of state-of-the-art design, development and processing equipment and as part of AMRC we also have access to the wide range of machining centres in the main Factory of the Future workshop, and the specialist services and resources of the other AMRC research groups.

Composite materials are increasingly used in aerospace, marine, automotive and other high-value industries for their combination of light weight and high strength. But they also present a host of manufacturing challenges.

Our research focuses on the production and machining of composite components, including hybrid parts which combine high-performance metals and composites in a single structure. Such structures can provide significant weight savings while maintaining the highest material and structural performance, offering improved fuel efficiency for aerospace and other transport applications.

Our main research area themes are:

- **Automated production**
- **Machining**
- **Advanced curing**
- **Novel materials and processing**
- **Dry fibre technologies**

The AMRC Composite Centre is a member of the Composites at Sheffield partnership.

Contact **compositecentre@amrc.co.uk** for further information.

Technical capabilities

Click page to jump

Our technology streams develop the techniques and underpinning science that can deliver significant improvements in engineering performance, including:

Equipment

Our core composite manufacturing equipment, mostly housed in the AMRC Factory of the Future:

Equipment index continues on next page...

Equipment

Click page to jump

...continued.

Dry Fibre Technology

Composite Machining

Machine Tools

Sensors

Composite Characterisation

Automated Production

Automation of composite manufacture is key to establishing future high-performance, cost-effective manufacturing solutions.

Working alongside other HVM Catapult's the AMRC utilises automated fibre placement and advanced robotic filament winding to demonstrate to SMEs, and its member companies, the cost and performance benefits of the technologies.

Our key resources include:

Research areas

- Developing in-process monitoring systems that improve system accuracy and reliability.
- Working with material suppliers to develop and evaluate new, process-specific materials.
- Developing software to provide a seamless transition from design to manufacture.

Industrial application and benefit

- Higher performance components resulting in lighter, more economical, designs.
- Improved material utilisation, up to 30% compared to conventional techniques.
- Significantly Increased productivity compared to traditional hand lay-up.

Also of note

The development of automated composite manufacturing technologies at the AMRC has allowed supply chains and SMEs to become involved in large-scale collaborative projects:

- Tinsley Bridge Group.
- UTAS.
- Automated Dynamics.
- TenCate.

This work supports these companies by providing a world-class facility to enable the demonstration of their products and expertise.

Advanced Curing

The curing process is key to converting a loose mass of fibres and resin into an advanced engineering composite material.

The curing process applies the energy to cross-link or melt the polymer matrix, and the pressure to consolidate a fibre reinforced composite. Autoclaves are traditionally used to apply this heat and pressure to produce high quality, low void composites. Despite the advantages of autoclaves, there are commercial drivers to use alternative out-of-autoclave (OoA) technologies to attain higher productivity and lower costs.

Advanced curing technologies

The AMRC is pursuing a number of enabling technologies and autoclave alternatives that will reduce costs and energy, whilst enhancing throughput and quality of components.
These include;

- Microwave heating.
- Hot pressing.
- Low and high pressure Resin Transfer Moulding (RTM).
- Directly heated tooling.
- In-situ consolidation during AFP.

Industrial application

The different technologies available will be of interest to different sectors of industry.

- Microwave curing is of key interest to the aerospace industry, with the process reducing cycle time and energy consumption without compromising part quality.
- Hot pressing is of great interest to the automotive industry; complex and relatively simple parts can be formed rapidly and accurately.
- For low-to-medium performance components not requiring autoclave pressure, directly heated tooling has great potential across all industry sectors.

Collaboration

- Directed work for OEMs such as Boeing and BAE Systems.
- Directed and collaborative research into thermoset and thermoplastic hot pressing for aerospace and automotive applications.
- International collaborative project with South Korean partners to investigate fusion bonding technologies for thermoplastic CFRP.
- EPSRC applications with Glyndwr University on microwave curing.
- Horizon 2020 project with the University of Sheffield on Smart Materials.

Novel Materials & Processing

The aim of the Novel Materials and Processing stream is to facilitate the development of processes and materials to improve net shape component manufacture and material properties.

The work undertaken by the Novel materials and Processing Technology stream typically falls into the following themes:

Joining

The Joining theme conducts research into the various methodologies for joining components to create assemblies with reduced manufacturing cost, improved joint design and utilisation and reduced qualification cost. Understanding the effect of such things as the influence of the bonding environment, surface preparation and bond thickness are vital for developing efficient, effective and reliable joining methods.

Tooling

The AMRC are undertaking research to develop tooling that is appropriate for a wide range of applications. The perfect tool would be durable, handle-able, low cost, have high temperature capabilities and a good Coefficient of Thermal Expansion (CTE) match with the component material.

The design of a tool can vary depending on its intended use - such as preforming, de-bulking and curing.

The development of 'intelligent' tooling – tools with added or increased functionality such as being reconfigurable or integrating sensors to monitor parameters such as pressure or temperature during cure – is an area of research that has the potential to significantly impact the manufacture of composite components.

Novel Materials

The novel materials theme facilitates the development and deployment of novel materials. The AMRC has a record of delivering successful projects on bio-composites, Metal Matrix Composites and core materials.

Our work on bio-composites has already made an impact on the production of bio-derived composites. Previous collaborations with SHD to develop materials and PES Engineering Ltd and TEKS UK for feasibility studies have given the AMRC strong foundations in this research area.

Simulation

The goal of our research in this area is to provide tools to aid decision making with respect to composite manufacturing through the development of process simulation and life-cycle analysis capabilities.

Being a relatively new field, many manufacturing decisions within the composites industry are made based on experience and opinion rather than science and fact. Often, a trial and error approach is used to find a manufacturing solution. Robust simulation will benefit the field of composites by minimising the use of materials and resources prior to component manufacture.

Dry Fibre Technologies

The manipulation of fibre architecture is key to producing an optimal component with tailored composite component performance.

The AMRC is working with traditional textile technologies, such as weaving and braiding, and pushing their capabilities beyond the conventional standards to produce novel composite fibre architectures.

Recent work includes the recreating of an automotive component - originally created using multiple 2D woven preforms joined together - using one single 3D woven preform.

Research Areas

- Developing new 3D architectures and understanding the mechanical property improvements offered by the new structures.
- Creating 3D preforms of optimal fibre positioning.
- Creating unitised single piece preforms for maximised fibre continuity.
- Preform infusion / conversion to composite (and intermediary processes).
- Developing software to allow improved 3D structure considerations (including damage response).

Industrial Application and Benefit

The novel preforming processes developed here at the AMRC yield the following benefits:

- Near net shape preforming.
- Thicker preforms.
- Reduced labour times as a direct result of the above.
- Higher performance components resulting in lighter designs.
- More accurate material deposition, and increased repeatability of composite conversion.

Also of note

The AMRC is well known for assisting supply chains in developing and demonstrating technology. This research theme has enabled this service to be extended to the technical textiles sector.

The AMRC's preforming capabilities have been utilised extensively in the cross-HVMC centre project - LSP.

Composites Machining

The composites machining group provides innovative, state-of-the-art and collaborative solutions to the composite machining community.

We want to make this form of subtractive composite processing affordable, fast and safe so that it is more attractive to machine a high value-add component to net shape than to use any other technology.

Recent works include assessment of CFRP workpiece quality inspection techniques and machinability techniques which have transferred from metallic traditions. These include surface roughness analysis, force measurement and tool micro-geometry inspection techniques. In addition, another project is looking at the effect of coolants on the CFRP machining process, focusing on the tool life impact.

Projects

Assessment of inspection techniques: Investigates 3D aereal texture measurement over typical stylus-based roughness measurement techniques to represent a complex, heterogeneous fibre reinforced polymer surfaces. In addition, this project also undertook to determine the efficacy of enhanced micro geometry in full slot edge trimming operations by investigating the forces in the process.

Wet vs Dry CFRP Machining: A number of different coolant types were used with all other factors in the experiment kept constant. The life of a number of drills was examined with respect to hole quality performance and tool wear criteria.

Industrial application and benefit

As industries such as aerospace, automotive and renewable energy (principally wind) look towards reducing the structural weight of their components, composite materials are growing in demand. Current large scale commercial aircrafts consist of more than 50% composites materials with a typical wing requiring in the region of 5,000 holes and more than 50,000 holes in the entire aircraft.

Also of note

Working with partners on generic projects or with companies on specific work the categories of development fall under:

- Cutting tool design benchmarking.
- Damage in composite machining.
- Intelligent workholding.
- Hole generation.
- Edge trimming.
- Stack material investigations.

This work supports these companies by providing a world-class facility to enable the demonstration of their products and expertise.

Automated Dynamics AFP

Machine Specification

- 7 axis system (6 axis robot plus spindle).
- Parts up to 1.2 m diameter, 2.75 m long & 2000 kg.
- 5 heads for different applications:
  - 4 x 1/4” tows of thermoset prepreg or thermoplastic bound “dry fibre”.
  - 1 x up to 1” tape of thermoplastic prepreg using laser heating for in situ consolidation.
  - 1 x up to 1” tape of thermoplastic prepreg using hot gas for in situ consolidation.
  - 1 x 3” tape of thermoset prepreg.
  - 12 x 1/8” tows of thermoset prepreg.
- All tapes/tows are fed and cut independently.
- Add/cut accuracy ±0.5 mm.
- Trajectory repeatability ±0.3 mm.
- Compaction force up to 90 kg (for tack, debulk & consolidation).
- Heating options: laser system, Hereaus Humm3 flash lamp and hot gas torch.
- ADC (native) & Autodesk (3rd party) programming.

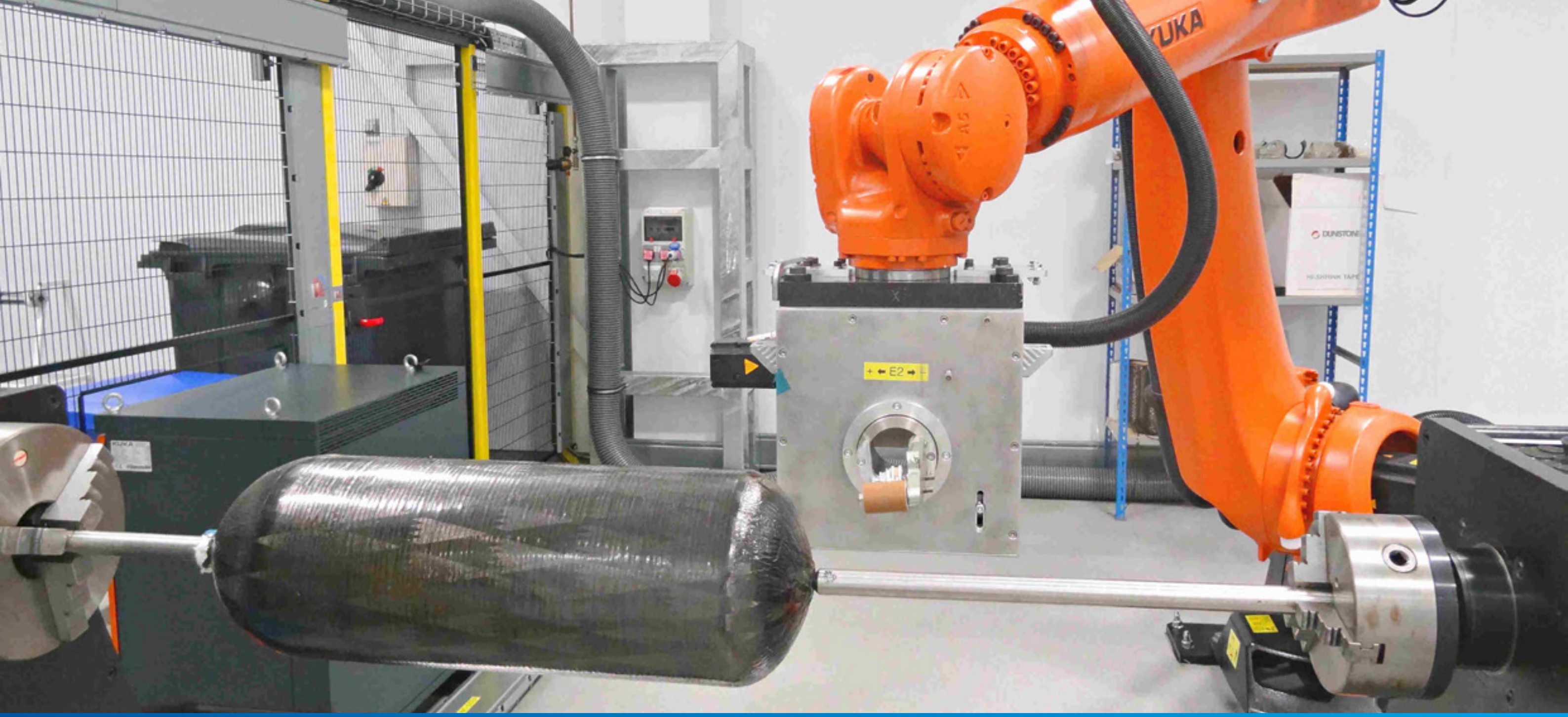
Advanced Fibre Placement Research

AFP developed from a combination of technology used for tape placement and filament winding, essentially moving tape placement onto a rotary axis to extend the range of parts which could be manufactured. Robotic AFP systems were developed in the last 10 to 15 years as a higher flexibility, lower cost solution compared to traditional machine tool setups and are now becoming more common place in the UK supply chain.

Much of the research at AMRC has focused on building a deep understanding of the process, from the programming through to the final product, with a combination of experimentation & demonstration on industrial scale components.

The key areas are:

- Part geometry & design for manufacture.
- Key data for programming & materials database.
- Defect characterisation (gaps, overlaps, wrinkles etc.).
- Effect of process parameters on quality & properties.
- Heating systems for tack control.
- Structural analysis of ‘as deposited’ structure.
- Models for selection of placement strategy.
- Innovative tooling.
- Smart structure design (ability to steer fibres to give unique structural stiffness).



High Tension Filament Winding - MF Tech

Machine specification

- 9 axis system (6 axis robot, spindle, rotating eye and material feed for AFP head)
- 2 end effector configurations
- Config 1 – Standard filament winding end effector
- Config 2 – Automated Fibre Placement (AFP) end effector
- Motorised headstock/slave chuck system
- Handle tool sizes from 5mm – 1500mm dimeter and 100mm – 4000mm in length
- Tool weights up to 2000kg+
- Spindle speeds of up to 250rpm <100mm diameter - 100rpm for 100mm> diameter
- - 4 tows, from 3k - 50k (tows) or 0.125" - 0.5" (pre-preg)
- High tension system up to 180N (±2N) per tow
- Integrated IR lamps for dynamic heating of pre-preg systems
- Heraeus Xenon system for processing thermoplastic materials
- Shrink/stretch tape application
- Mandrel inflation system for Type IV vessel manufacture
- Spray binder application for constraining dry fibre systems
- Mandrel over tension system
- Capable of winding flat, spar, non-axisymmetric and multi-axis parts.
- Integrated data logging system (tension, temp, axis positon, spindle speed, etc)
- COMPOSICAD and Cadfil programming – pipe, vessel, axisymmetric, spar, curve & tee.

Background and projects

Following on from the introduction of the AMRC's existing filament winding machine commissioned back in 2013, the AMRC have now added the latest iteration of MF Tech robotic system to their capability which was commissioned in April 2019.

The high tension system exhibits many new capabilities, namely the ability to wind at nearly twice the tension of the previous machine, this benefits part manufacture such as the over winding of electric rotor magnets and composite flywheel solutions. The other stand out capability is the introduction of the automated fibre placement end effector, this allows the ability to deposit true 0° plies within a typical filament layup, something that cannot be done without huge complexity within a traditional filament winding setup. It also brings the capability of producing multi axis flat panels.

Other notable capabilities include the ability to stabilise dry fibre with an integrated binder application system, a mandrel inflation system for pressurising polymer tools when winding Type IV pressure vessels and a mandrel over tension system for applying high tensions to the mandrel to avoid deflection and retain concentricity when winding with high tensions on thin mandrels. With the integration of the Heraeus Noble Light System we also have the capability for in situ processing of thermoplastic materials.

Expert Robotic Pick and Place Cell

Cell Features:

- ABB 6-axis robot
- Automated tool changer and storage posts for 2 end-effectors
- Pneumatic drawer system for ply storage
- Assyst Bullmer CNC ply cutter can load plies into cell

Gripping capability:

- Needle grippers (pneumatic and electric)
- Coanda (high flow vacuum) grippers
- Bernoulli (non-contact) grippers
- Matrix gripper

Robotics:	AAB IRB 6640
Handling:	1 small and 1 large Vacuum Gripper with electrically driven needle grips
Storage:	Eight Pneumatic driven Drawer Material storage unit
Other:	MK Belt Conveyor Item Assembly table

Microwave Curing Systems

Microwave curing technology can hold significant benefits over conventional methods when applied to composite structures. These benefits include reduction in cycle times and manufacturing space, as well as improvement in energy efficiency.

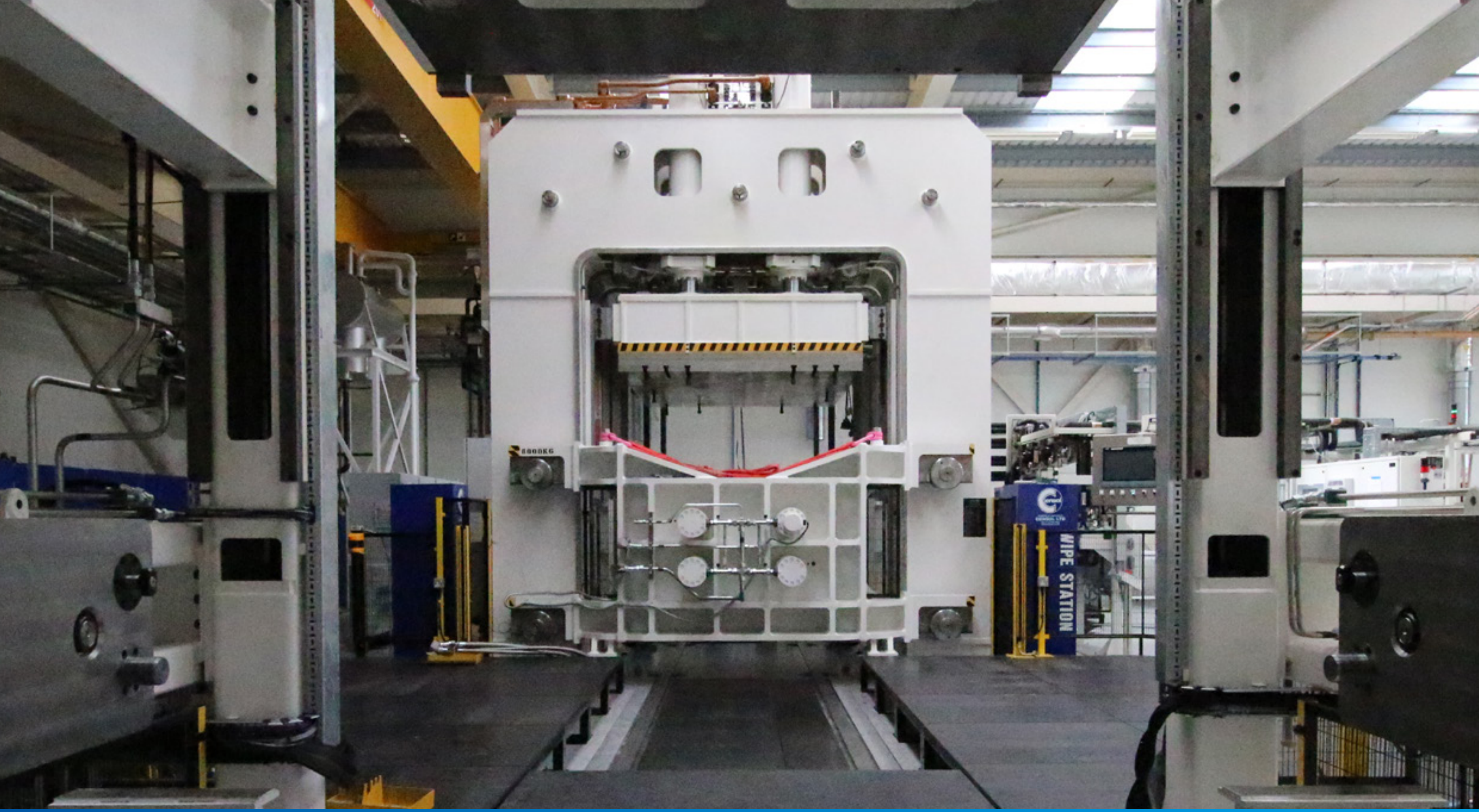
AMRC have two microwave systems: Vötsch industrial and Panasonic test bed. The Vötsch microwave operates at a frequency of 2.45GHz and consists of 24 magnetrons (21kW power). Located within the ceiling of the cavity are two infrared cameras to view the heat distribution of a composite within the whole chamber.

The test bed is based off a 1kW Panasonic domestic microwave and its bespoke feature is the novel control system. The system can be operated using one of five intelligent control algorithms to explore the full potential of high speed curing.

Areas of research include: material characterisation (absorbing, transparent and reflective materials), processing of thermoset and high temperature thermoplastic composites, modelling of the microwave chamber, cure optimisation of a prepreg material, equipment development and tooling materials.

Machine Type:	Vötsch Microwave Chamber
Specification:	24 magnetrons @ 2.45 GHz, 900w x 24 = 21kW
Internal Dimensions:	1.8m x 1.5m x 2.1m
Temperature Monitoring:	K-Type Thermocouples Fibre Optic Thermocouples (up to 450°C) Optris IR Cameras
Safety Systems:	FOT's and IR cameras integrated into control system Fire suppression unit
Other:	Microwave compatible vacuum system

Machine Type:	Panasonic Retrofitted test bed
Specification:	1 magnetron, 2.45 GHz, 1000W
Internal Dimensions:	354 mm x 343 mm x 205 mm
Temperature Monitoring:	Fibre Optic Thermocouples (up to 450°C)
Other:	Microwave compatible vacuum system



Rhodes Group Hot Press

1000 tonne press – designed to be used for HP-RTM, Gap-RTM, Pre-Pregs, Compression-RTM, Moulding of Thermoplastics and Thermosets.

- Rear mounted, lower shuttle table for tool loading
- Heating system up to a maximum temperature of 290°C
- 1000 tonne achieved by eight 250 mm/180 mm diameter double acting main rams
- Tool area ranging from a minimum of 975 F/B x 1075 L/R up to 3300 F/B x 2300 L/R
- 1800 mm open daylight and 500 mm closed daylight
- Operating speeds: Rapid approach 38 mm/sec, press up to 255 Bar up to 2.5 mm/sec (variable) and return 40 mm/sec

Machine Type:	Rhodes Group Hot Press
Envelope:	Bed: 2800mm x 2300mm Stroke: 1200mm
Load:	10MN
Max Temperature:	280°C
Rapid Travel Speed:	150mm/s
Pressing Speed:	2mm/s
Control System:	Siemens

Langzauner Hot Press

Machine Type:	Langzauner Heated Press
Envelope:	Bed 1500mm x 1000mm Stroke 700mm
Load:	320 tonne giving 20 bar over full platen face
Max Temperature:	390°C
Ramp Rates:	Heating 5°C / min Cooling 5°C / min
Heating Power:	72kW
Rapid Travel Speed:	100mm / s
Pressing Speed:	0-14mm / s

RTM Machines

Machine Type:	Krauss Maffei HP RTM
Capacity:	100kg
Max Pressure:	200bar
Temperature:	130°C
Max Flow Rate: (2 machines in parallel)	24kg/min
Injection heads:	4
Other:	Exotherm quench system Fully intergrated with Rhodes press

Machine Type:	Isojet RTM system
Capacity:	10 litres
Max Pressure:	7 bar
Temperature:	120°C
Additional Features:	Vacuum system, two part resin systems Flow or pressure control

Autoclaves & Curing Oven

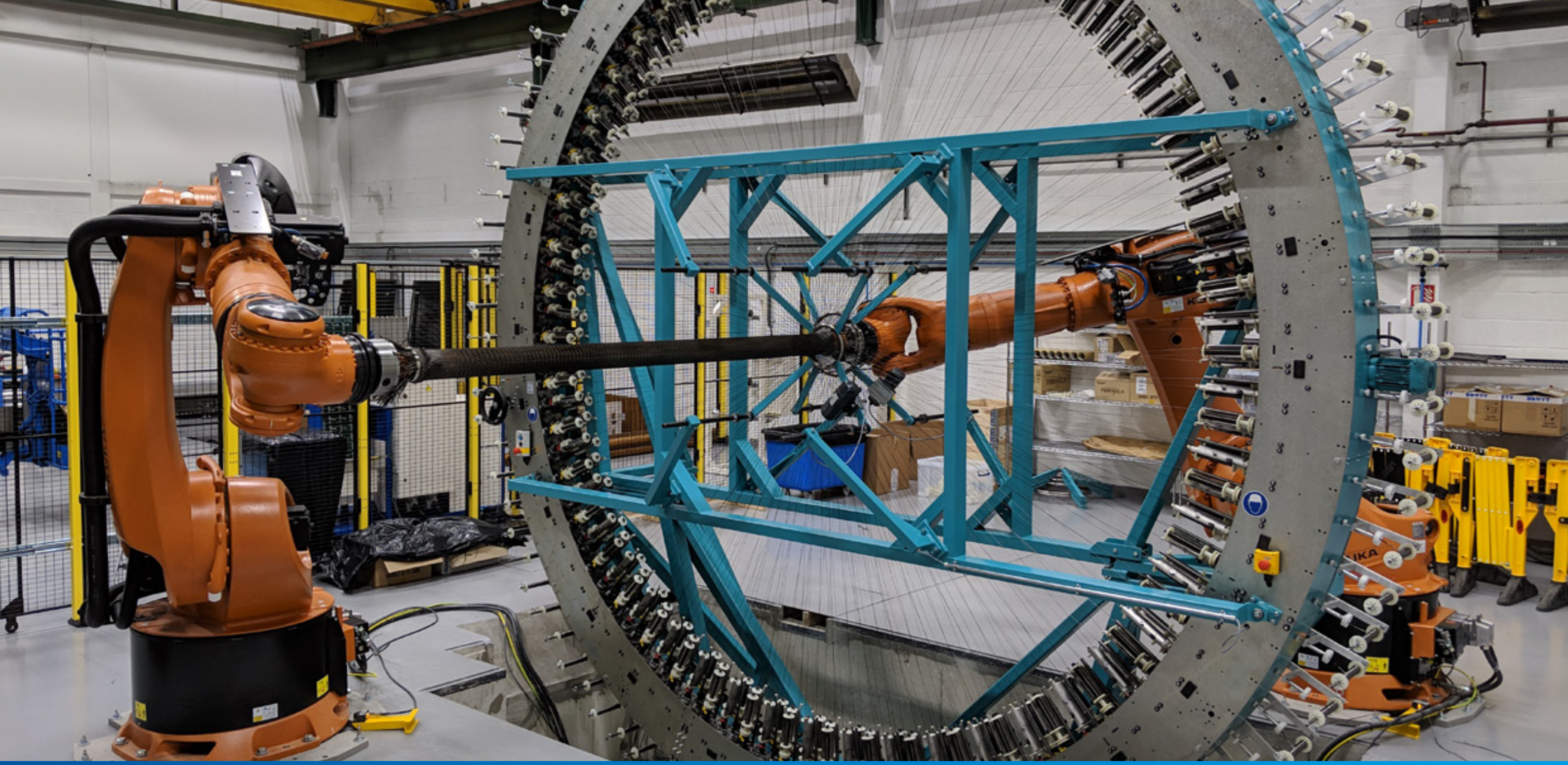
Machine Types:	LBBC Autoclaves
Volume:	a) 3000mm diameter x 5000mm long b) 1000mm diameter x 2000mm long
Temperature:	a) 210°C b) 400°C
Pressure:	a) 10 bar b) 20 bar
Power:	a) 60kW b) 180kW
Atmosphere:	Nitrogen

Machine Type:	Caltherm Curing Oven
Volume:	3000mm x 3000mm x 3000mm
Temperature:	210°C
Power:	95kW
Atmosphere:	Air

Rapier Weaving Loom

- Loom capable of weaving 2D & 3D preform cross sections
- These structures are important for introducing damage resistance and tolerance
- Customize architectures, use multiple (hybrid) fibres etc.
- 20 weaving shafts
- 4 colour weft
- Carbon fibre processing capable
- High Speed Double Rapier with positive fibre transfer
- 1.5M weaving width

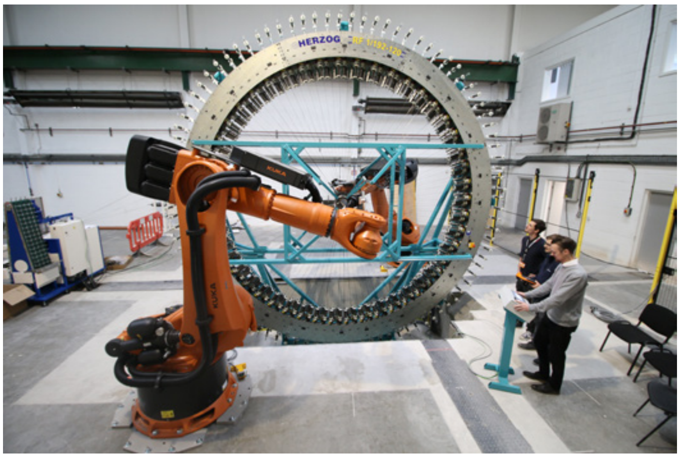
Type	Fast Technology Rapier Weaving Loom
Fibres	Carbon, Glass, Kevlar, Basalt, Alumina
Fibre count/tow size	1K – 24K
Fabric architecture	Single-layer, Multi-layer, Cellular – converted to 3D structures
Fabric width	1000mm (nominal), 800mm (minimum) 1400mm (maximum)
Shedding system	Dobby
Number of Heald frames	28
Weaving speed	Up to 300 pics/minute
Pick density	Variable – depending upon fibre count
Weft feed	4 colours (weft insertions) available. Possible to insert multiple wefts. Potential for metallic weft yarns.

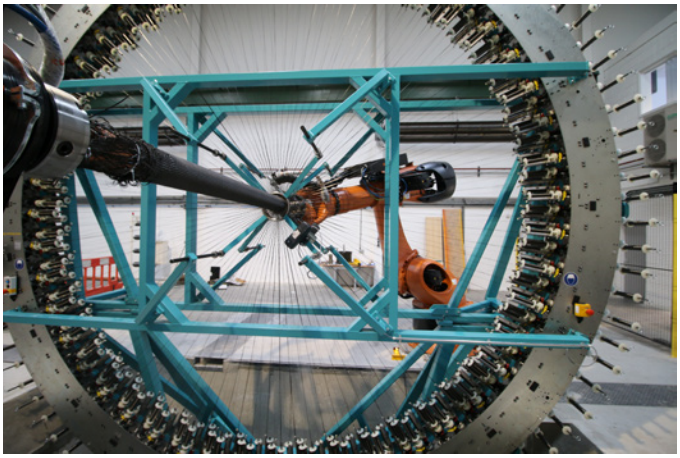


Herzog Radial Braiding

Fabrication of carbon fibre preforms by braiding technique

- Variety of tows can be combined in the axial and braid directions in order to create hybrid materials
- Non-interlaced core materials such as fibre tows, foam materials, metal wires, fibre optics and smart actuating materials can be over braided using the technology
- Ability to form complex shapes is one of the key features of braiding technology
- Radial bobbin configuration for low fibre damage and maximum flexibility on part shape
- Triaxial setup
- 192 bias carriers, 96 axial
- Dual robot part manipulation, 6 axis
- Part size up to 2.8m long by 0.7m depending on fibre angle requirement
- Mandrel weight up to 300kg
- Bias angle from 10 to 80deg
- CF tow size from 3K to 50K
- Carriers for delicate fibres (eg carbon, ceramic etc) and other fibres (eg glass, polymer etc)

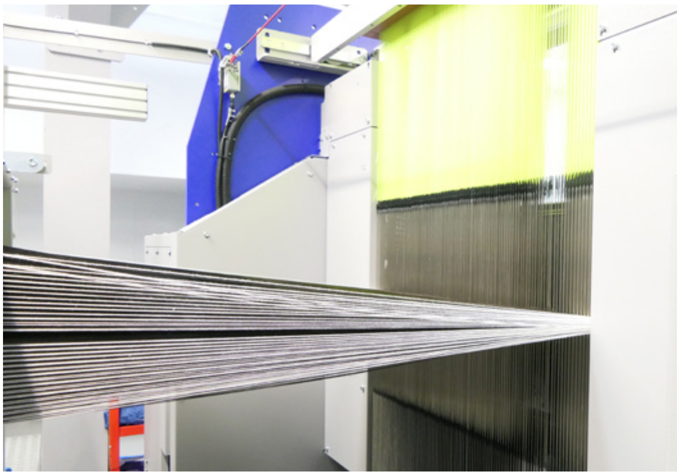


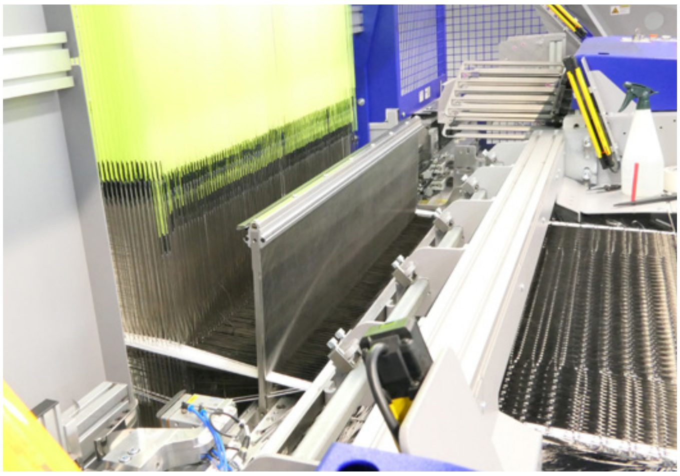


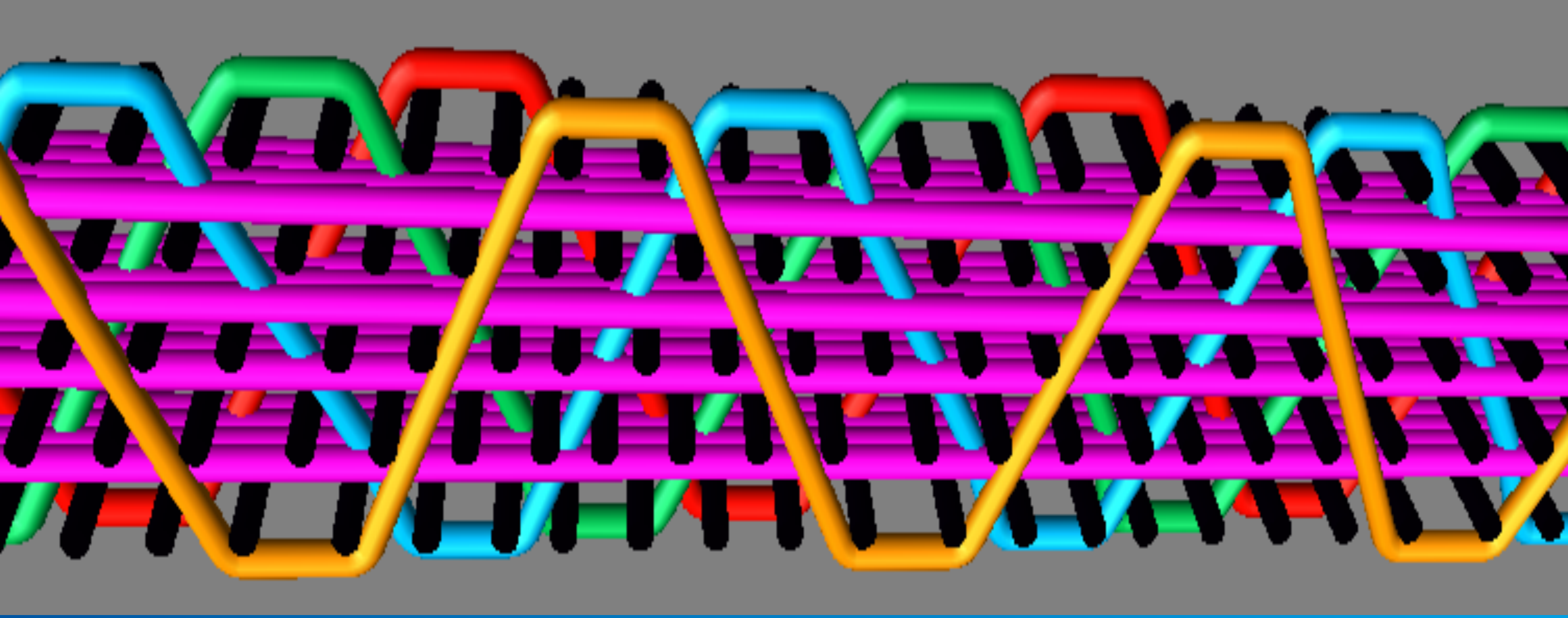
Jacquard 3D Weaving Loom

Complex Jacquard Weaving System. Loom capable of weaving Complex 3D geometries in x, y & z directions.

- State of the Art Staubli Unival Jacquard with independent warp fibre control
- Free selection of system components in terms of warp thread supply, shed formation, weft insertion and fabric take-off
- Flat take up to maintain fibre orientation and reduce distortion
- Unlimited freedom in design
- Production of very dense fabrics over 5cm thickness
- Warp: 3072 fibres in warp direction supplied by a bobbin creel
- Weft: double-rapier weft insertion system
- Weaving width: ~ 1 m
- Efficient processing of a wide variety of technical and highly sensitive fibres (e.g. carbon, glass, metallic, aramid etc.)
- Can be optimally adapted to a product-specific requirement (e.g. flat, spacer, complex multi-layer fabrics)



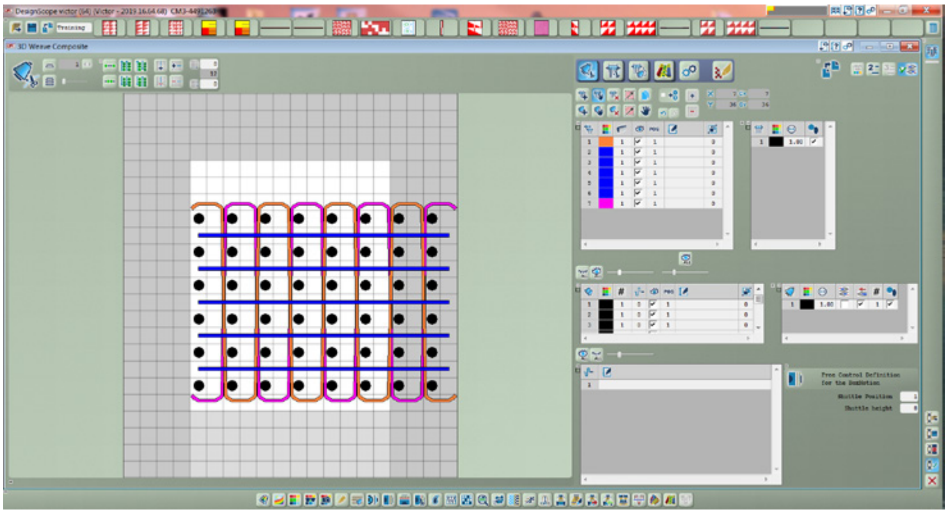


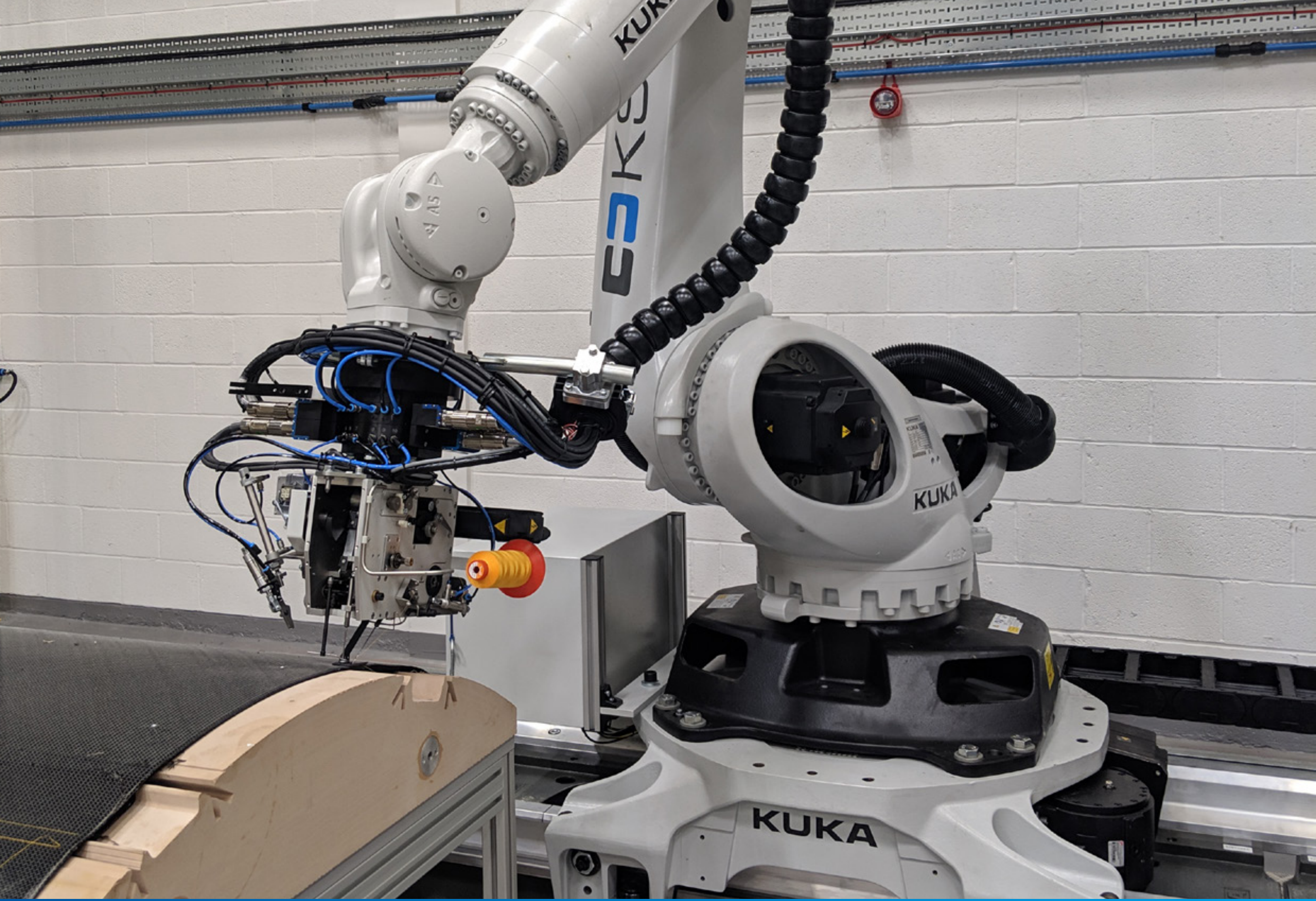


EAT Jacquard Weaving Design Software

Complex geometries can be created using Weave Design Techniques combined with EAT advanced Design Software.

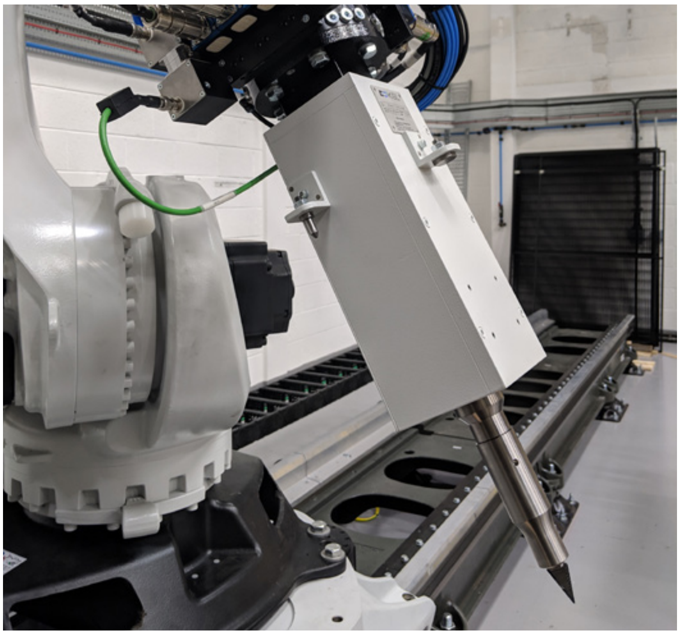
- Advanced Design Software enables complex Solid structures to be manufactured.
- Infinite number of weave possibilities for optimising fibre paths and creating shapes as well as solid fibre blocks.
- Programming of Unival 100 Jacquard to enable multiple shed geometries and reduce filamentation during fibre processing.
- Simulation illustrating fibre cross sections





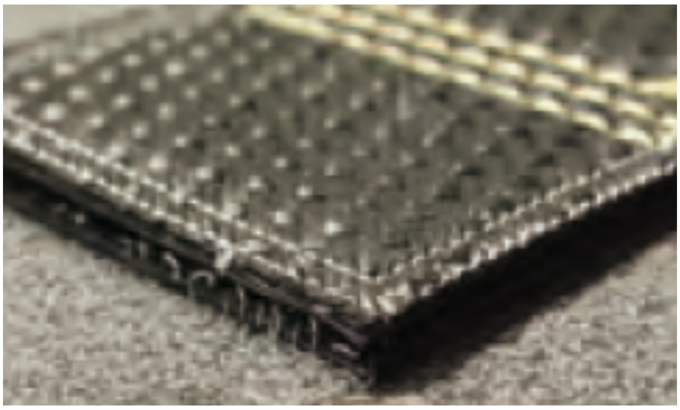
Robotic Stitching and Trimming

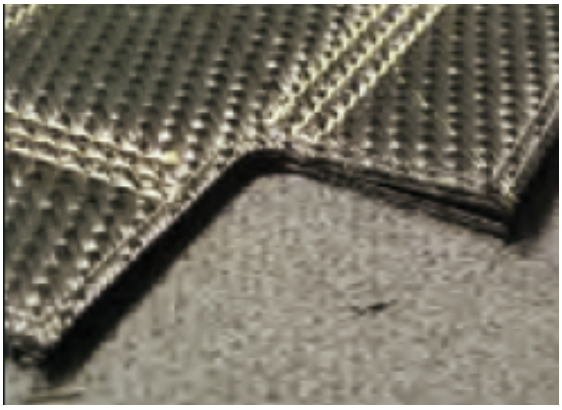
- KSL robotic stitching and trimming robot for preform assembly, trimming and through thickness reinforcement
- Working envelope 7m x 3m x 2m.
- 2 different stitching heads for single side stitching
- Ultrasonic knife for preform trimming
- 7 axis Kuka KR150 robot on a 7 m long track.
- 150Kg payload capability at max reach of 3m.
- Positional accuracy of stitch or trimming +/-0.5mm
- Stitch or trim paths manually taught or programmed with Kuka PRC software

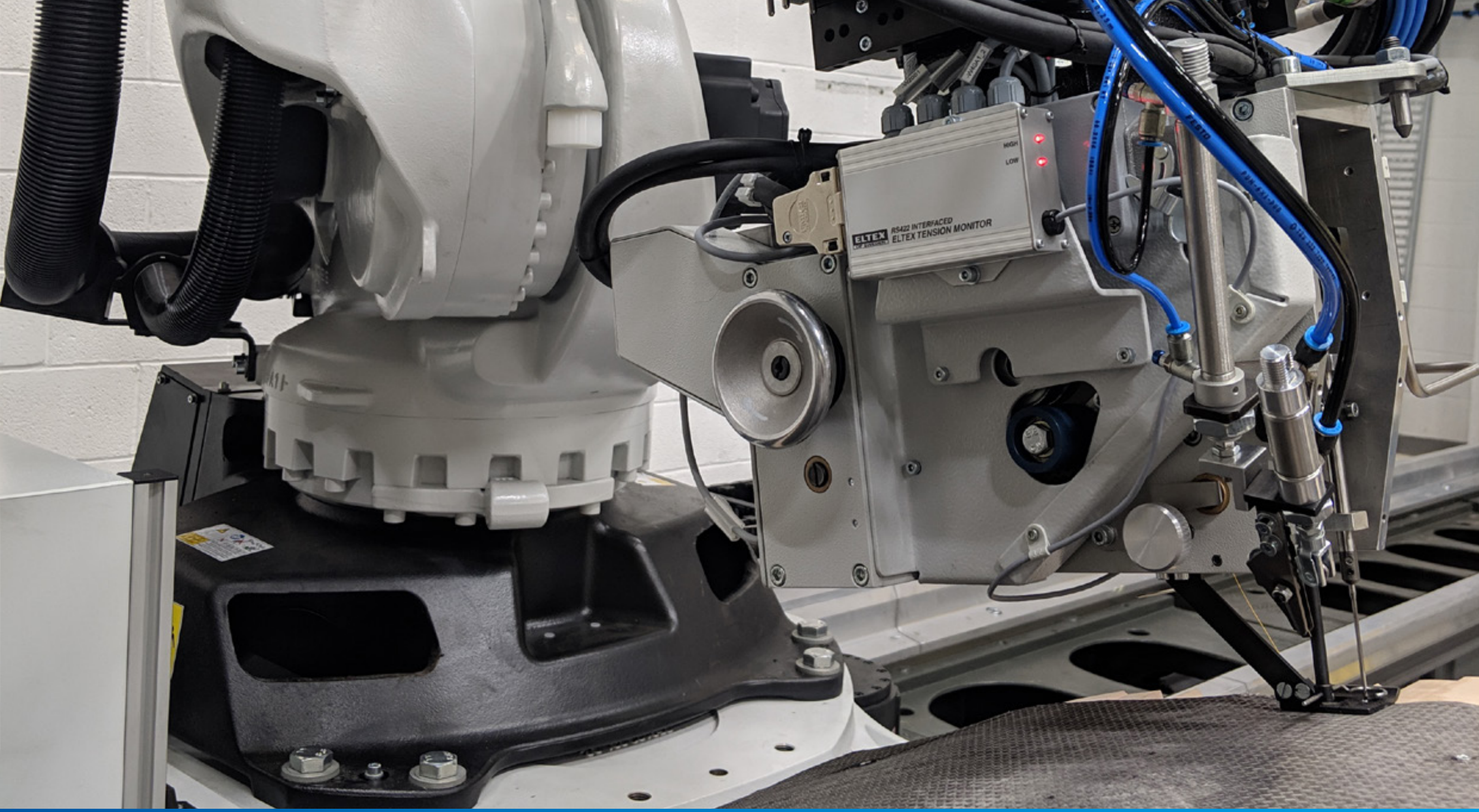


Ultrasonic Robotic Trimming

- Large ultrasonic trimming knife.
- Allows 3d trimming of preform edges and details.
- Up to 20mm thick thickness, dependant on material type.
- Up to 20m/min cutting speed, dependant on material type.
- Can cut dry fabric, un-cured prepreg, nomex honeycomb.

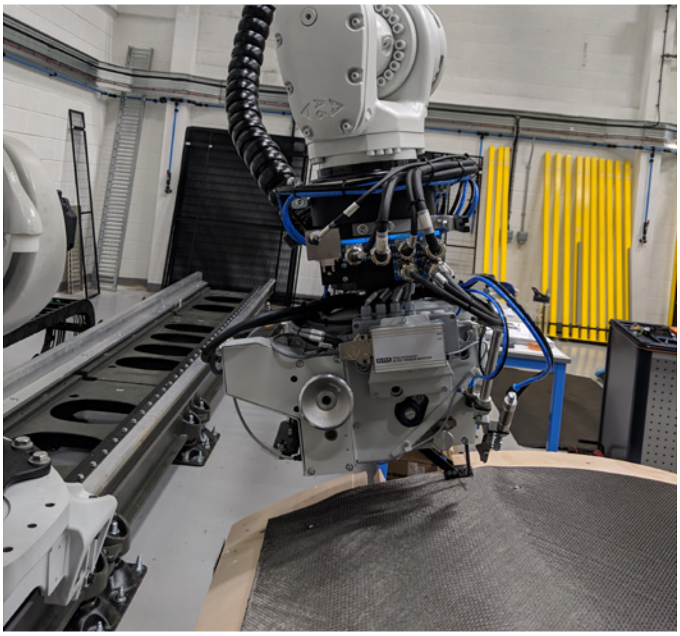


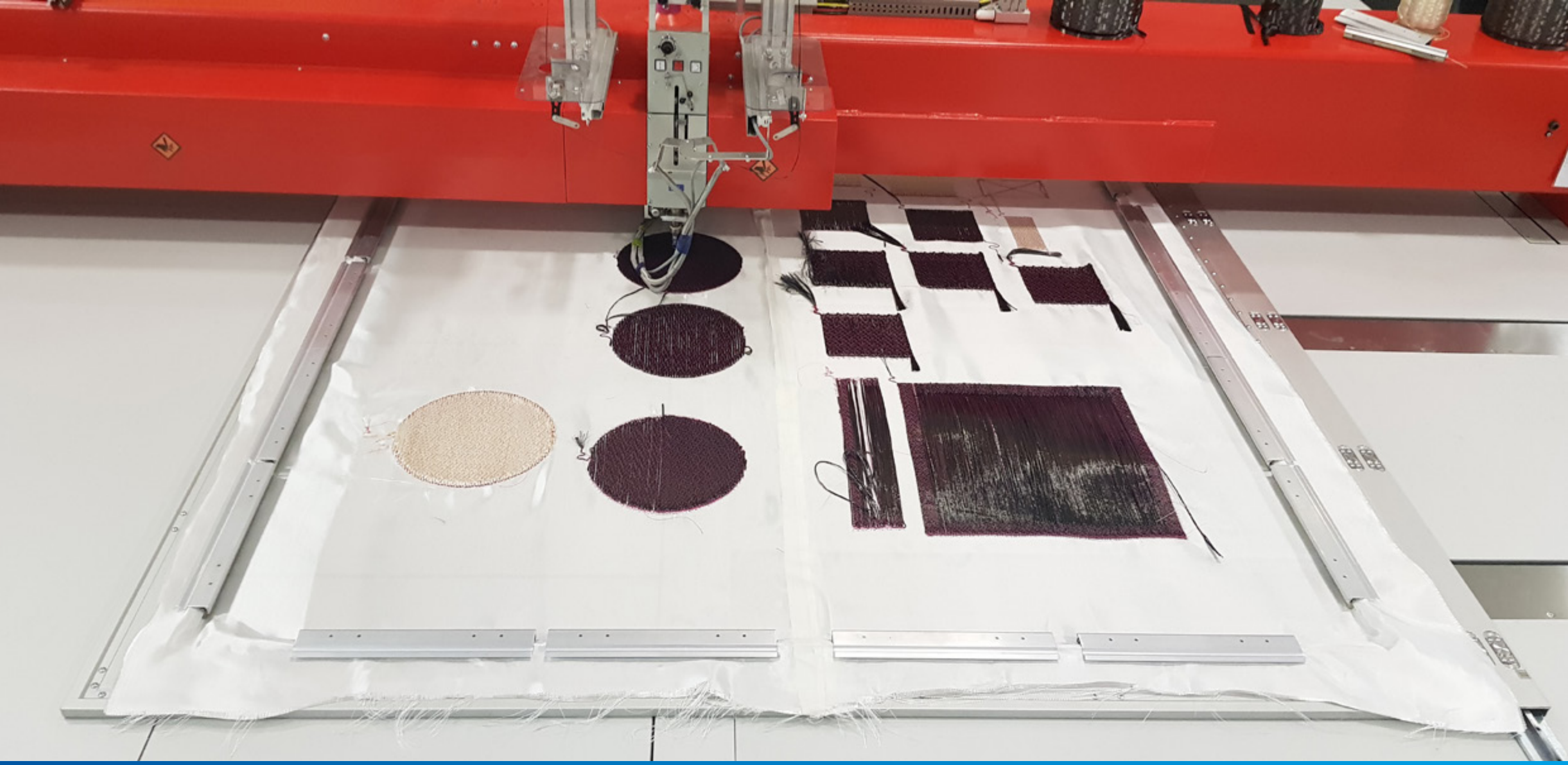




Stitching Heads

- Both stitching heads stitch from one side only, so can stitch much larger structures than would be capable with a conventional sewing machine which needs access from top and bottom.
- Can stitch around 3d geometries, so a wing skin, pressure bulkhead, chassis, etc.
- Stitching thread can be carbon, Kevlar or polyester.
- Automatic thread cutting at end of stitch.
- Stitch tension monitoring available as an add on extra.
- Preform thickness up to 20mm, dependant on stitch thread, preform material, level of compaction, binder type etc.





Tailored Fibre Placement - TFP

Cost-effective Embroidery system

Tailored Fibre Placement (TFP) is a dry fibre manufacturing technology for composite applications which can reduce structural weight by putting fibre only where it is needed.

- TFP use through –thickness reinforcement and stitching to overcome interplay delamination and reduces waste of expensive fibre.
- It can manufacture multiaxial reinforcements of many plies, to many thicknesses, with precise and complex fibre architectures
- Preform dimension: up to 2 × 1.5 m^2
- Stitching thickness : up to 5.5 mm
- Automated process permitting complex detailed fibre placement
- Easier material handling
- Creation of net-shape parts
- Customizing shape and fibre orientation
- Placement of continuous tows in any direction by rotating a stationary stitching unit
- Adapted to different fibre types (carbon, glass, Kevlar, thermoplastic towpreg/filament…) and various tow count (1K to 50K)

Fibre placement in all orientation

Layers disposition in all direction

Fast linking

EasyPerm

3D permeability measurement device

Easyperm measures the permeability of a dry reinforcement in-plane (XY Configuration) and through thickness (z Configuration)

- The only industrial solution to simulate the capacity of reinforcement to be impregnated by a liquid resin.
- Adapted to all types of fibre (carbon, glass, aramid, flax, hemp etc.)
- 6 pressure sensors granting the acquisition of permeability values in different positions

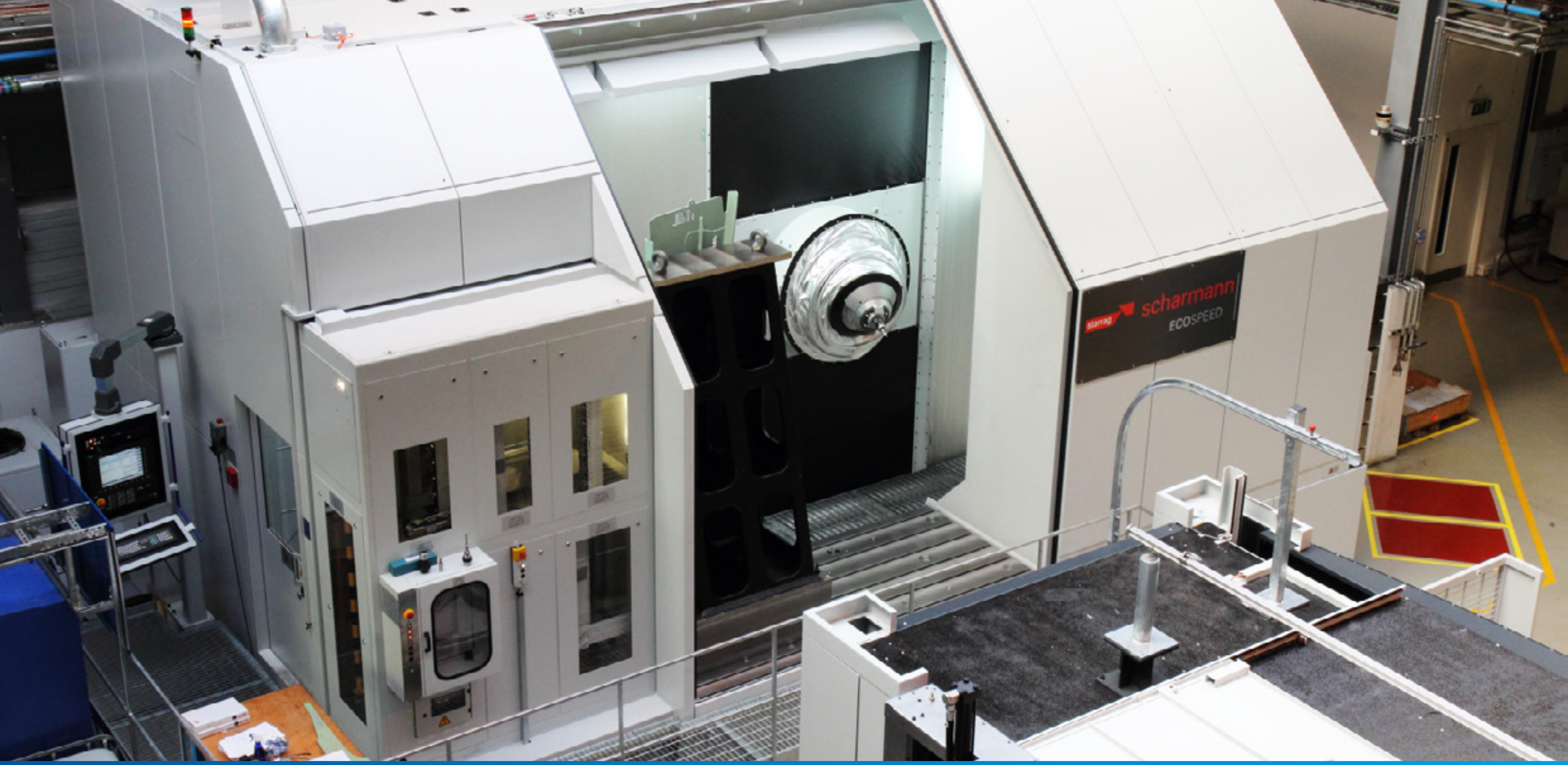
5-axis CMS Ares and Antares CNC Machining Centres

Machine Type:	5-Axis Ares CMS CNC Machining Centre
Envelope:	X-Axis 4800mm Y-Axis 1800mm Z-Axis 1200mm
Power:	12kW
RPM:	24,000
Coolant:	MQL or dry cutting with extraction system

Machine Type:	5-Axis Antares CMS CNC Machining Centre
Envelope:	X-Axis 2600mm Y-Axis 1500mm Z-Axis 1200mm
Power:	12kW
RPM:	24,000
Coolant:	MQL or dry cutting with extraction system

Additional supporting equipment

- Kistler 9129AA plate dynomometer with base plate and holder for lathe and machine base use.
- Kistler 9170A Rotating components dynamometer.
- FLIR A655sc Infrared thermal imaging camera.
- Photron FastCam SA-X2 High Speed Camera.

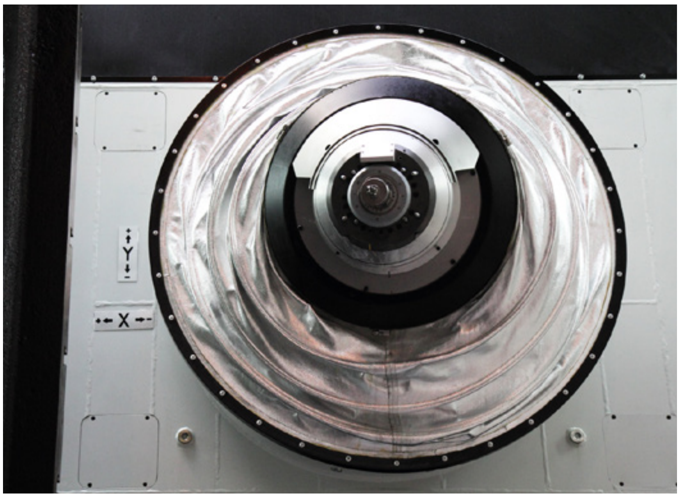


Scharmann Ecospeed

The Ecospeed is designed for high-speed five-axis machining of monolithic aluminium and composite aerostructures.

It features the Z3 parallel kinematic head, which can follow any path within a conical working envelope of ±40º, mounted on a column with 3.8 metre X and 2.5 metre Y-axis travel. Our machine is also specified for wet cutting of carbon fibre composites.

Machining envelope	Size: 3800mm x 2500mm x 670mm (horizontal) / 370mm (±40°) Max. table load: 3000kg Parallel kinematics
Cutting fluid delivery	High pressure coolant (HPC) through-tool Minimum quantity lubrication (MQL)
High-speed spindle	Power: 120 kW (S1) Torque: 83 Nm Max. RPM: 30,000 Synchronous
HSK-A tool connection	Maximum rigidity 63 diameter Capable of accepting E-type Max. acceleration A/B axes: 685°/s^2 Max. jerk move: 50 m/s^2
Controller: Siemens 840D	CAD/CAM interactive Toolkit for control & compensation MPC mach. protect. control



Doosan Puma SMX3100L Mill-Turn

The Puma SMX Series is a multi-tasking mill-turn machine, integrating the capabilities of a vertical machining center and horizontal turning center into one platform.

Machining capacity	• Swing over bed / saddle & max. machining diameter: 630mm (X axis), 2585(Z axis) +-150mm (y axis), +-120 degrees (B axis), 360 degrees (C Axis) • Max. workpiece / turning dimensions: 660 mm X 2540 mm • 102mm Bar working diameter
Cutting fluid delivery	• Through-tool coolant: 20 Bar • Flood delivery
Turning spindle	• Spindle nose: A2#11 • Power: 25kW (cont. / 30min rate) • Max. speed: 3000 rpm • Max. torque: 1203 Nm
Milling spindle	• Power: 15 kW • Max. speed: 12,000 rpm • Interface: HSK 63 A
Controller	Siemens 840D SL (TBC)
Accuracy	• X / Y / Z / axis – positioning: 0.02 mm • Repeatability: 0.01 mm • B / Z axis positioning: 0.0067 deg • Repeatability: 0.0045 deg
Wet / Dry configuration	CFRP machining ready in both wet and dry environments with added air curtains and dust extraction unit

DMG Mori 340G linear US-A

Dynamic machining of large workpieces

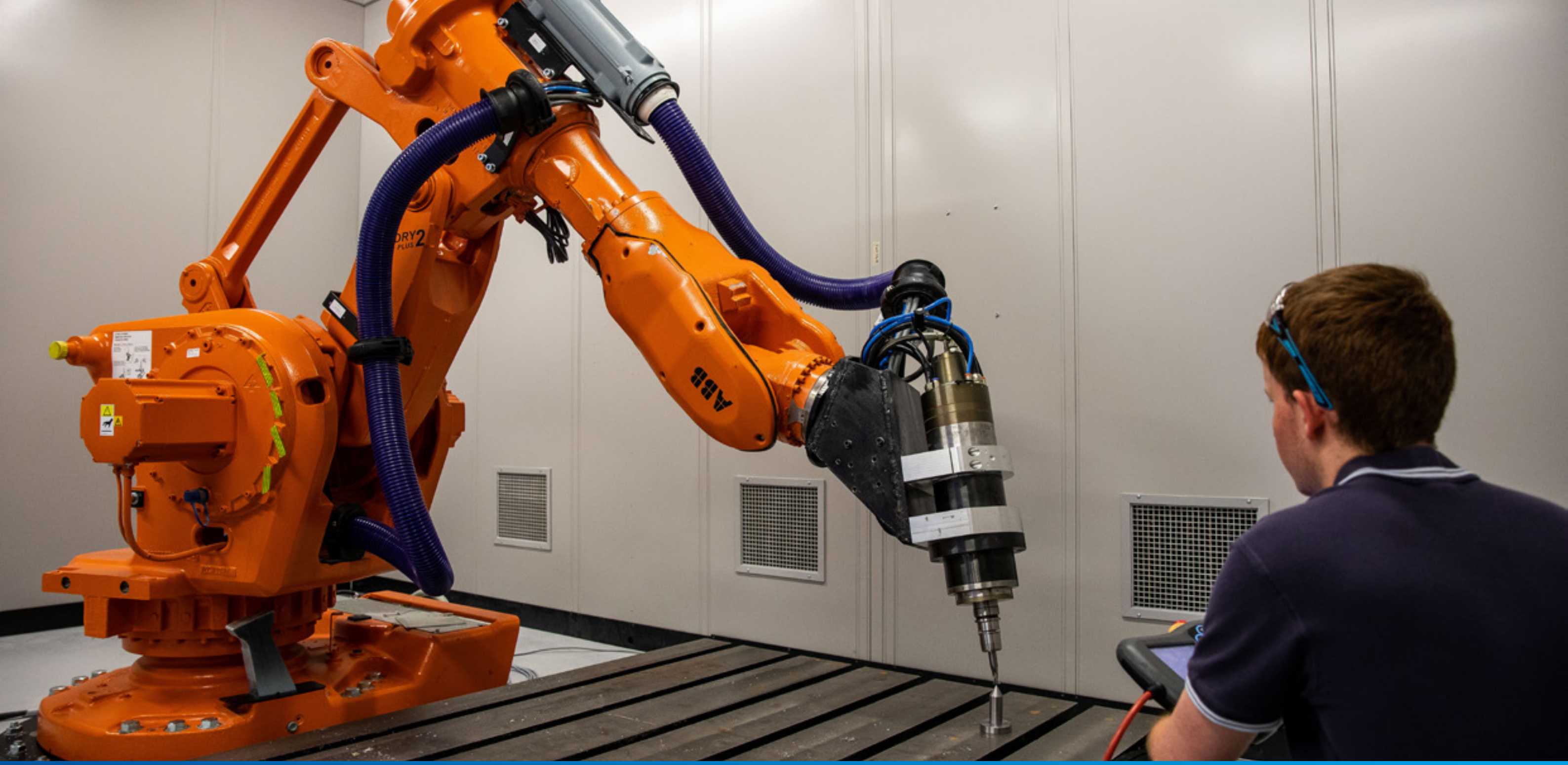
Platform	**Machining envelope** X: 3400 mm Y: 2800 mm Z: 1250 mm B: 0° to +210° C: 0 ° to 360 ° **Cutting fluid delivery** • 2500 litre coolant supply @ 26 l/min • Ext. /Int.(10 - 80 bar) flood • Ext./Int. MQL + air • Frequency controlled • Stepless pressure program. by NC
High-speed spindle	• Power: 35kW • Max. RPM: 20,000 • Torque: 135 Nm • Synchronous type • YRT 325 bearing
HSK-A tool connection	• Maximum rigidity • 63 diameter
Ultrasonic assisted machining	• Sauer Vs: 17 kHz to 30 kHz with up to 15 µm amplitude • Wireless energy transmission • Adaptive parameter tuning

Controller: Siemens 840D SL Op. + CELOS	• CAD/CAM interactive • 3D quickset • Toolkit for control & compensation • MPC mach. protect. control • OMATIVE adv. adapt. Control • CELOS visualisation of US-A
Linear drives	• High Kv-Factor: 3-5 m/mm*min • Acceleration: 3 m/s^2 • Jerk: 30 m/s^3 • Drive stiffness: theoretically ∞
Renishaw probing	• Type PP60 optical

Flow Aquarese AWJ

Ultrahigh-pressure abrasive waterjet cutting and machining.

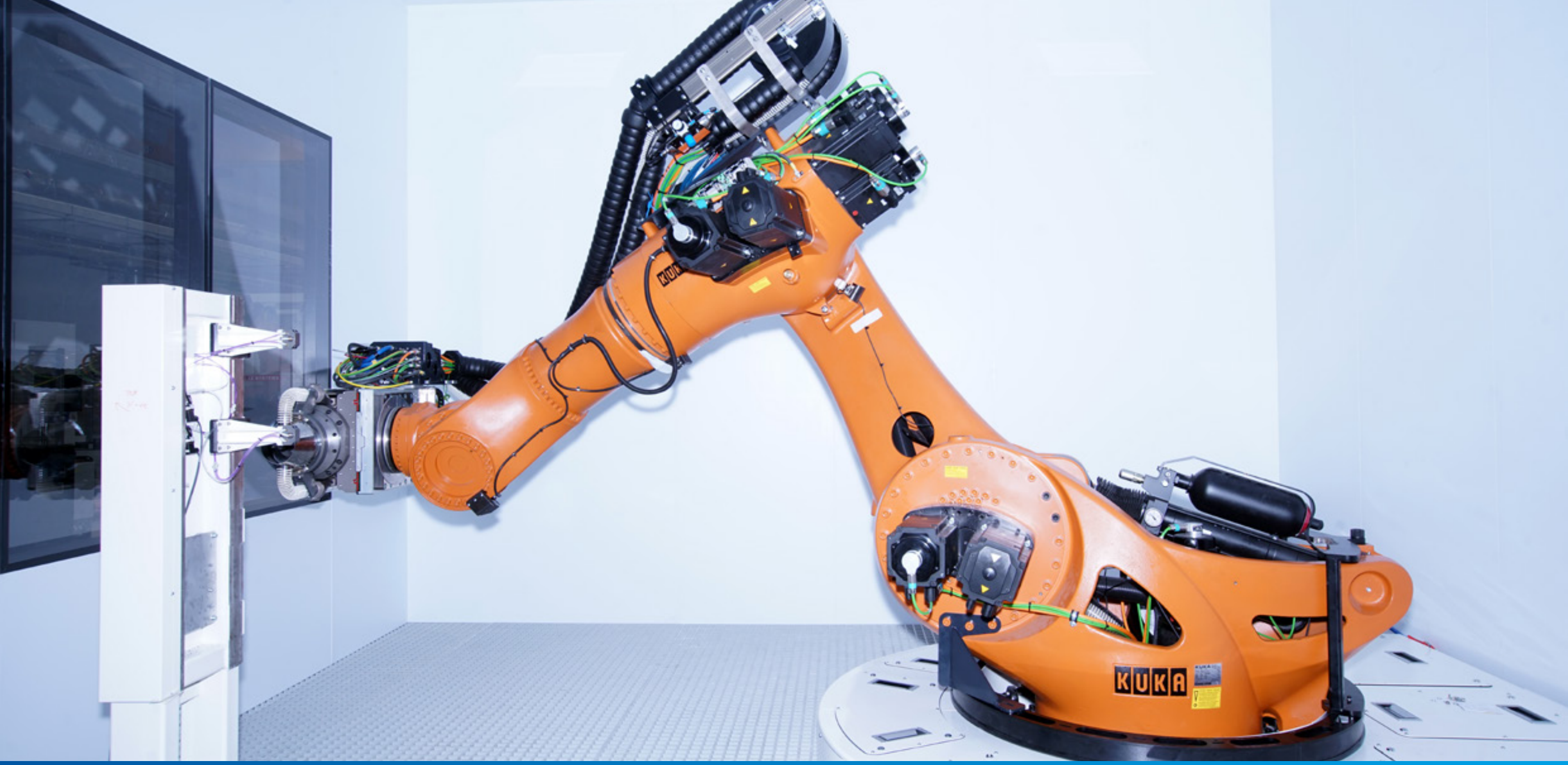
6-axis Staubli TX200 robot	• Extended tilting angle of the tool (±100°) and an extended Z travel (900 mm) • Max. reach: 2,194 mm • Max. payload: 130 kg • Position/path repeatability: 0.06 mm • Net working area (2D cutting): 1000 x 2000 mm
FLOW PASER® 4 Cutting Head	• Pressure range: 1,200 to 6,500 bar (10 to 94 kpsi) provided by Hyper jet 94i -D 100 hp • Manual flowrate control by metering disc
Abrasive supply system	• System of Abrasive Management (SAM) 200 kg • 2 Tm bulk hopper
Controller:	**Staubli CS8C HP** • AquaCAM3D software for path generation and probing • Tool-radius compensation • Automatic cutting program generation • Cutting program simulation with cycle time estimation • Human-Machine Interface (HMI): Beckhoff PC with the Aquarese machine interface and Windows 7 Pro • Mobile robotic control pendant to move the axes in jog mode



6-axis ABB IRB 6660 robot

The IRB 6660 is an extremely reliable robot designed for high performance applications.

Machining envelope	• Max. reach: 3100 mm • Max payload: 205 kg • Repeatability: 0.07 – 0.11 mm
External laser probing/ alignment	• Leica T-Scan
High-speed spindle	• Peron PS TCV-1-SP • Power: 15 kW • Max. torque: 14 Nm @0-10000 rpm, 6 Nm @ 10000-24000 rpm • Max. RPM: 24000
HSK-A tool connection	• 50 diameter • High-speed low torque applications
Controller	**IRC5 with FlexPendant** • High-level RAPID programming language • RobotWare software • PROFIBUS DP interface board • AC500 integrated PLC



KUKA KR 1000 L750 'Titan' robot

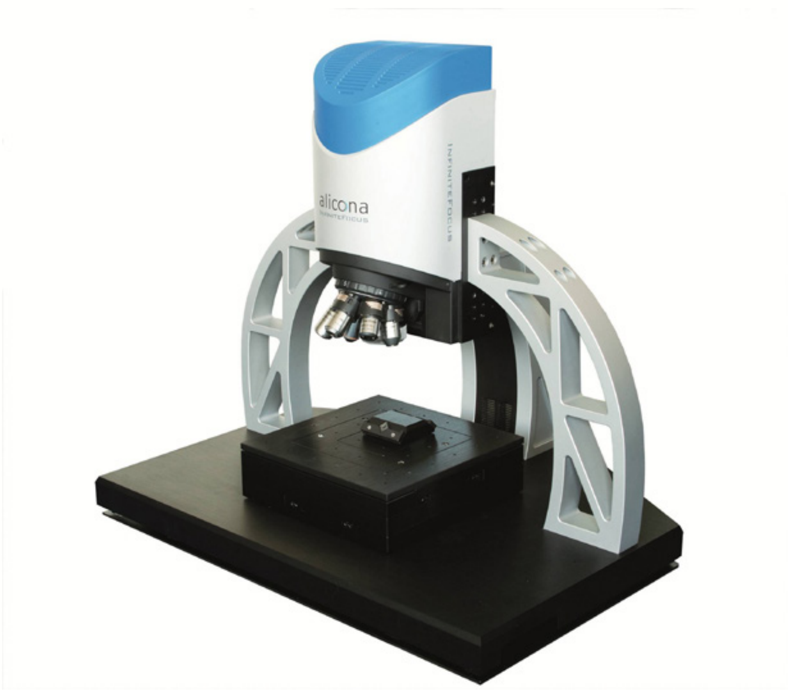
The KR 1000 Titan LR750 is a heavy-duty 6-axis robot capable of bridging distances of up 7.5 m and handling payloads of up to 750 kg. Titan is used as part of the Accurate Robotic Machining System (A.R.M.S.), built as collaboration with the AMRC, ElectroImpact, Siemens, Renishaw and funded by Innovate UK.

Machining envelope	• Max. reach: 3601 mm • Max payload: 750 kg • Accuracy: ±0.2 mm throughout the majority of the working volume • Retrofitted Renishaw encoders in joints for enhanced repeatability • Renishaw probe
High-speed spindle	• GMN HCS 280 – 18000 / 60 • Power: 60 kW • Max. torque: 174 Nm • Max. RPM: 18000
HSK-A tool connection	• 100 diameter • Mid-high speed high torque applications
Controller	**Siemens 840D** • Siemens HT2 remote pendant • CAD/CAM interactive • Toolkit for control & compensation • MPC mach. protect. control

Kistler 9170A RCD

The KR 1000 Titan LR750 is a heavy-duty 6-axis robot capable of bridging distances of up 7.5 m and handling payloads of up to 750 kg. Titan is used as part of the Accurate Robotic Machining System (A.R.M.S.), built as collaboration with the AMRC, ElectroImpact, Siemens, Renishaw and funded by Innovate UK.

Type	Force sensor
4-components rotating dynamometer	• Max. RPM: 20000 • Measurement range – Fx, Fy: ±5 kN – Fz: ±20 kN – Mz: ±150 Nm • ER32 collet type • Up to Ø20 mm tool shanks
HSK-A tool connection	• 63 mm diameter (HSK63A) • Through-tool fluid delivery capable up to 70 bar



Alicona InfiniteFocus G5

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Type	• Optical Surface Measurements • Three-dimensional, non-contact
Measurements	• Surface profile and form measurements • Areal roughness measurements • Cutting edge geometry • Tool wear: flank, edge rounding & edge recession
Magnification	• 2.5x, 5x, 20x, 50x, 100x
Resolution	• Vertical 2.3µm – 10nm • Min measurable Ra- 0.03 µm • Min measurable Sa- 0.015 µm • Min measurable radius- 0.1 µm

FLIR A655sc

Type	• Infra-red camera
2 measurement ranges	•-40°C to +100°C • +100°C to +650°C
Detector	• Spectral range: 7.5-14.0 µm • Resolution: 640 x 480 • Pitch: 17 µm • Framerate: – 200 Hz @ 640 x 120 – 100 Hz @ 640 x 240 – 50 Hz @ 640 x 480
Interface	• Gigabit Ethernet • USB (limited to 25 Hz framerate)
Optics	• 24.6 mm focal length – Field of view (FOV): 15 ° x11.3° – F number: f/1.0 – Spectral band: 7.5-14 µm • Optional macro lens: – FOV: 64x48 mm – F number: f/1.0 – Spectral: 7.5-14 µm

Romer Absolute arm 8525 with Verisurf

Specifications	• 7 Axis 2.5m reach with a scanning laser head and touch probe capability • Absolute Encoders and SMART Sensors
Interface	• Laser Scanner with point acquisition rate of 750,000 points with a resolution of 48 microns • Ruby Touch probe with accuracy of 12 microns
Software specifications	• Ability to calculate Local Waviness • Catia based Plug-in that can create and use model based definitions (MBD) • Reverse engineer of parts from real life to CAD solids not just STL.

Photron Fastcam SA-X2 480K M1

Type	High-speed camera
1 Megapixel CMOS sensor	• Resolution/framerate – 1024 x 1024 pixels at 12,500fps – 1024 x 1000 pixels at 13,500fps – 768 x 768 pixels at 22,500fps – 512 x 512 pixels at 45,000fps – 512 x 376 pixels at 60,000fps – 256 x 280 pixels at 120,000fps • Max. framerate: 480000 fps • 64GB internal memory
Interface	• Remote computer control via high-speed dual port Gigabit Ethernet
Triggering	• Programmable delay on selected input and output triggers, 100ns resolution • Start, end, center, manual, random, random reset, Random center, random manual, image Trigger
Optics	• Interchangeable Nikon F-mount – Compatible with Nikon G-type lenses – Optional Canon EF remote control mount

Characterisation Equipment Suite

AMRC Composite Centre offers an extensive range of analysis equipment for the characterisation of composites and their constituent materials.

A state-of-the-art thermal analysis laboratory is equipped with differential scanning calorimetric, thermal mechanical, thermo-gravimetric, reaction systems, density and rheometric analysis equipment, allowing the investigation of reaction kinetics, degree of cure, glass transition temperature, volume fraction, porosity and viscoelastic properties.

Perkin Elmer DSC 4000 – Differential scanning calorimetry	Records heat flow over a sample, allowing for cure analysis and heat capacity measurements.
Perkin Elmer DMA 8000 – Dynamic mechanical analysis	Dynamically loads a sample over a temperature range to find its viscoelastic properties.
Perkin Elmer TGA 8000 – Thermo-gravimetric analysis	Allows for weight fractions of samples to be found by burning off during the weighing process
TA DHR-1 Rheometer – Rheometric analysis	Measures the viscosity of a material between two plates, allowing for cure and gel times and viscoelastic response to be investigated
Perkin Elmer Spectrum 2 FTIR – Infrared spectroscopy	Identifies material constituents by comparing infrared spectra reflected off samples.
Anton Paar Multiwave Pro – Microwave acid digestion	Microwave heating assisted acid burn off method to find volume fraction of samples
SNOL Laboratory Furnace – Furnace burn off	Furnace burn off method to find volume fraction of samples
Micromeretics Accupyc 1340 – Pycnometry	Uses nitrogen gas displacement to measure volume and density of materials.
HotDisk TPS2500 S – Dielectric Property testing	Measures thermal conductivity, diffusivity and volumetric specific heat of materials.
Cark Zeiss LSM 800 – Confocal laser scanning microscopy	Laser scanning microscopy allows for precise 3D imaging of material surfaces.

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