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Advanced Manufacturing Research Centre

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AMRC Composite Centre
Capability directory

CATAPULT
High Value Manufacturing

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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.

Based in a dedicated extension to the AMRC Factory of the Future, we extend the AMRC's expertise in metals production into the new generation of carbon fibre composite materials. These 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.

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

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Machine and Manufacturing Capabilities

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

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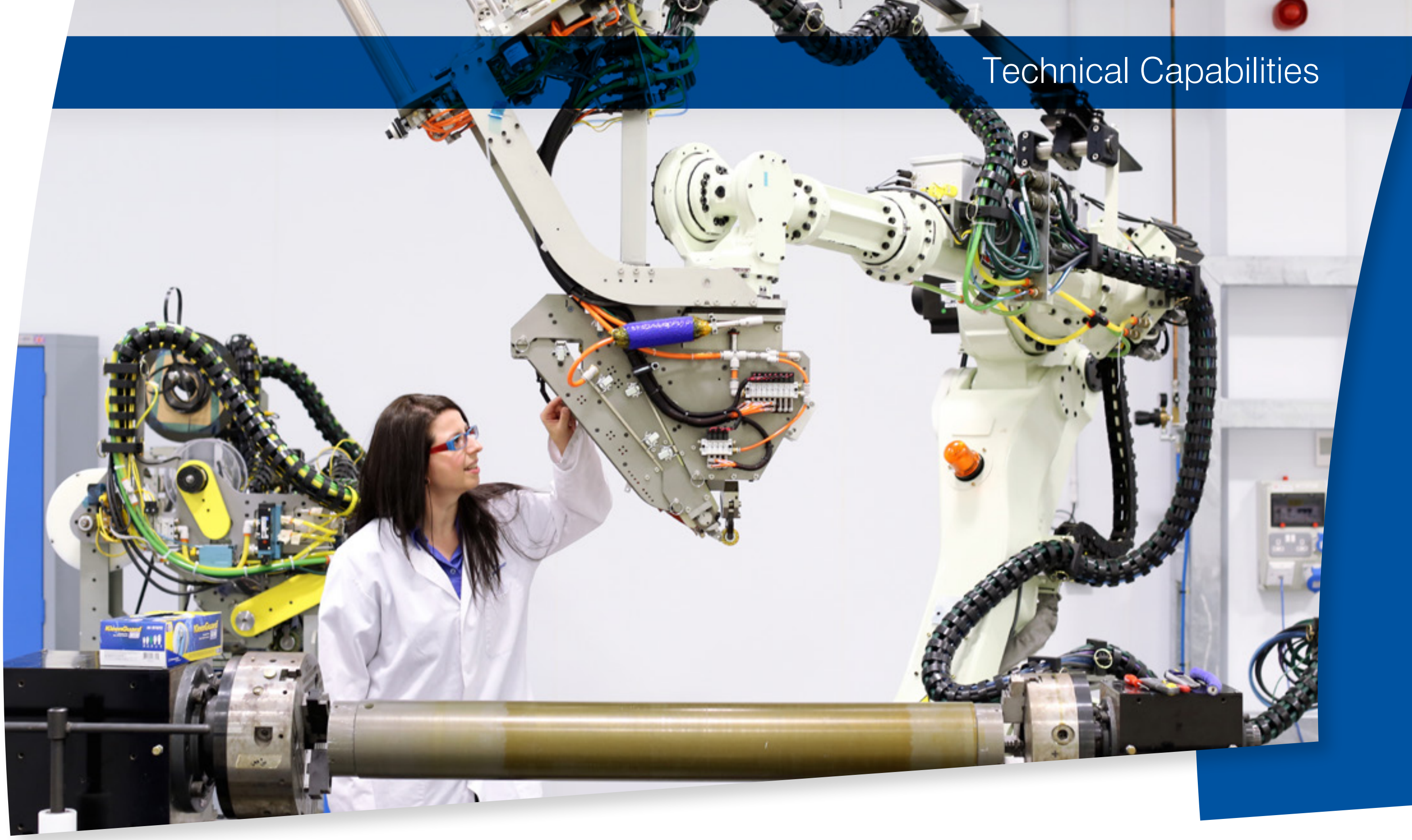

Composite Equipment

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.

Our key resources include:

- ADC robotic fibre placement system with thermoplastic tape/tow, thermoset tape and multi-tow thermoset capability.
- MF Tech robotic filament winding machine with wet/dry and prepreg capability.
- Expert Robotic Pick and Place cell.
- Kraus Maffei HP RTM 4 port injection equipment.
- Isojet Combi RTM equipment.
- LBBC autoclave, 3m x 5m, 10 bar, 210°C.
- LBBC autoclave, 1m x 2m, 20 bar, 400°C.
- Caltherm curing oven, 3m x 3m x 3m, 230°C.
- Hedinair curing oven, 1m x 1m x 1m, 300°C.
- Vötsch microwave curing facility, 1.8m x 2.8m, 450°C.
- Langzauner laboratory press, 300 tonne, 400°C, 1m x 1.5m platen, suitable for thermoset/thermoplastic processing, thermoforming, RTM etc.
- CMS Ares 5 axis machining centre.
- CMS Antres 5 axis machining centre.
- Eastman NC ply cutter, 2m x 4m.
- Assyst Bullmer converyorised bed ply cutter, 2.2m bed width.
- WIS Double Diaphragm former, 3m x 1.8m.
- Rapier Weaving Loom.
- Mega 5 tooling capacity.
- ISO class 8 clean room, 900 sq m with integral freezer.
- Patran and Nastran FEA software.
- Modelling, design and simulation software, including WiseTex, Catia V5, PTC Creo, MSC Suite (Patran, Nastran, Mentat, Marc and Dytran) and PolyWorks.
- High performance Lenovo workstation, 32 cores, 896GB RAM dedicated for simulation.
- SimaPro life cycle assessment software.

Automated Production

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

Working alongside other CATAPULTs 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.

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.
- Novel materials.
- Simulation.
- Tooling.

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.

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.

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.

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

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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.

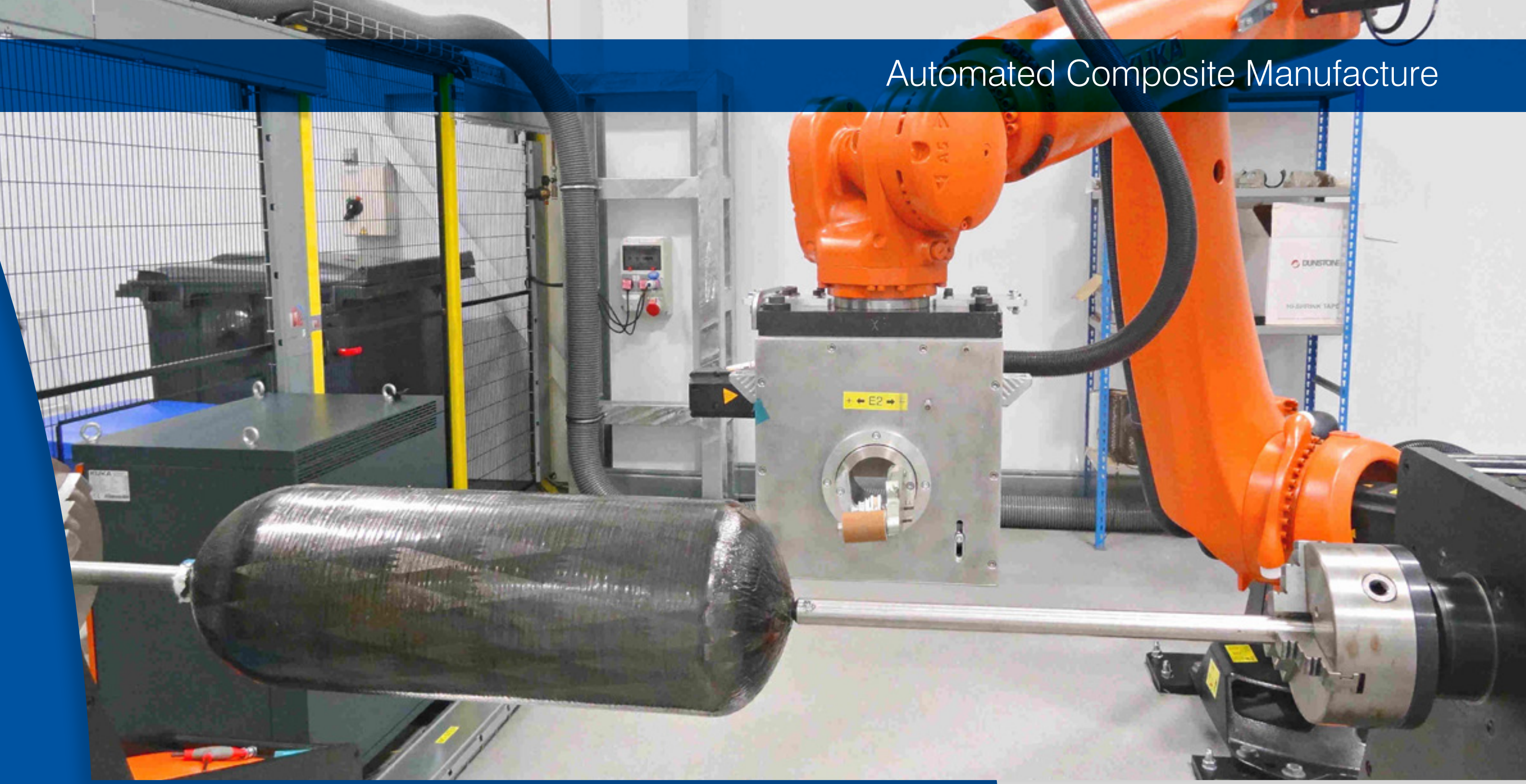
Advanced Fibre Placement Research

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).



MFTech FW

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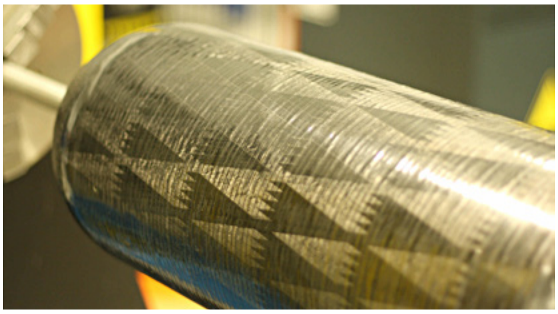
Machine specification

- 8 axis system (6 axis robot, plus spindle & rotating eye).
- 2 winding setups: Process 1 – Mandrel held on horizontal spindle.
- Process 2 – Mandrel held & rotated by robot.
- Process 1 – Parts up to 1.2m diameter, 4m long & 2000kg.
- Process 2 – Parts up 1m diameter, 1.2m long, limited to 90kg.
- Max spindle rotation speed 100rpm.
- Capable of winding flat, spar, non-axisymmetric & multi-axis parts.
- - 4 tows, up to 24K or ½" wide each.
- Wet winding (up to 100°C resin heating), dry or prepreg/towpreg winding.
- Thermoplastic winding with Hereaus Humm3.
- Tension up to 100N (±2N) per tow.
- Shrink/Stretch tape application.
- COMPOSICAD and Cadfil programming – pipe, vessel, axisymmetric, spar, curve & tee.



Filament winding research

Filament winding has existed as a composite manufacturing process for many decades, but the use of robotics is a more recent development, initially researched in the 1990's and commercialised by MFTech, France in the 2000's.

The use of robotics can offer more flexibility, even though the standard setup often mirrors that of a traditional CNC winder. The AMRC facility, supplied by MFTech, can operate in a traditional winding setup as well as by mounting parts on the robot and integrating pre and post winding operations into the robotic cell. Commissioned early 2013, it has been used for a wide range of composite research projects for manufacturing products such as:

- Pressure vessels.
- Electric rotor magnet retention.
- Torsion actuation shafts.
- Torsion beam suspension links.
- Propeller blades.
- Anti roll bars.
- Prop shafts.
- Rapid preforming for RTM.
- Fuel pipes.
- Designer furniture.

Expert Robotic Pick and Place Cell

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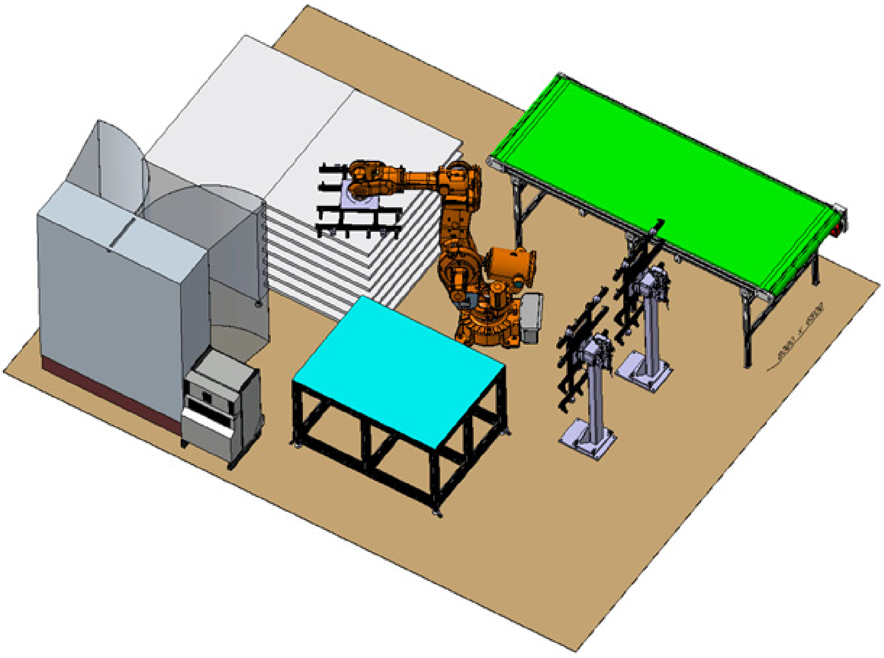
Robotics:	AAB IRB 6640
Handling:	1 small and 1 large Vacuum Gripper with electrically driven needle grips
Storage:	Eight Pneumatic driven Drawer Material storage unit
Other:	MK Belt Conveyor Item Assembly table



Microwave Curing Systems

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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

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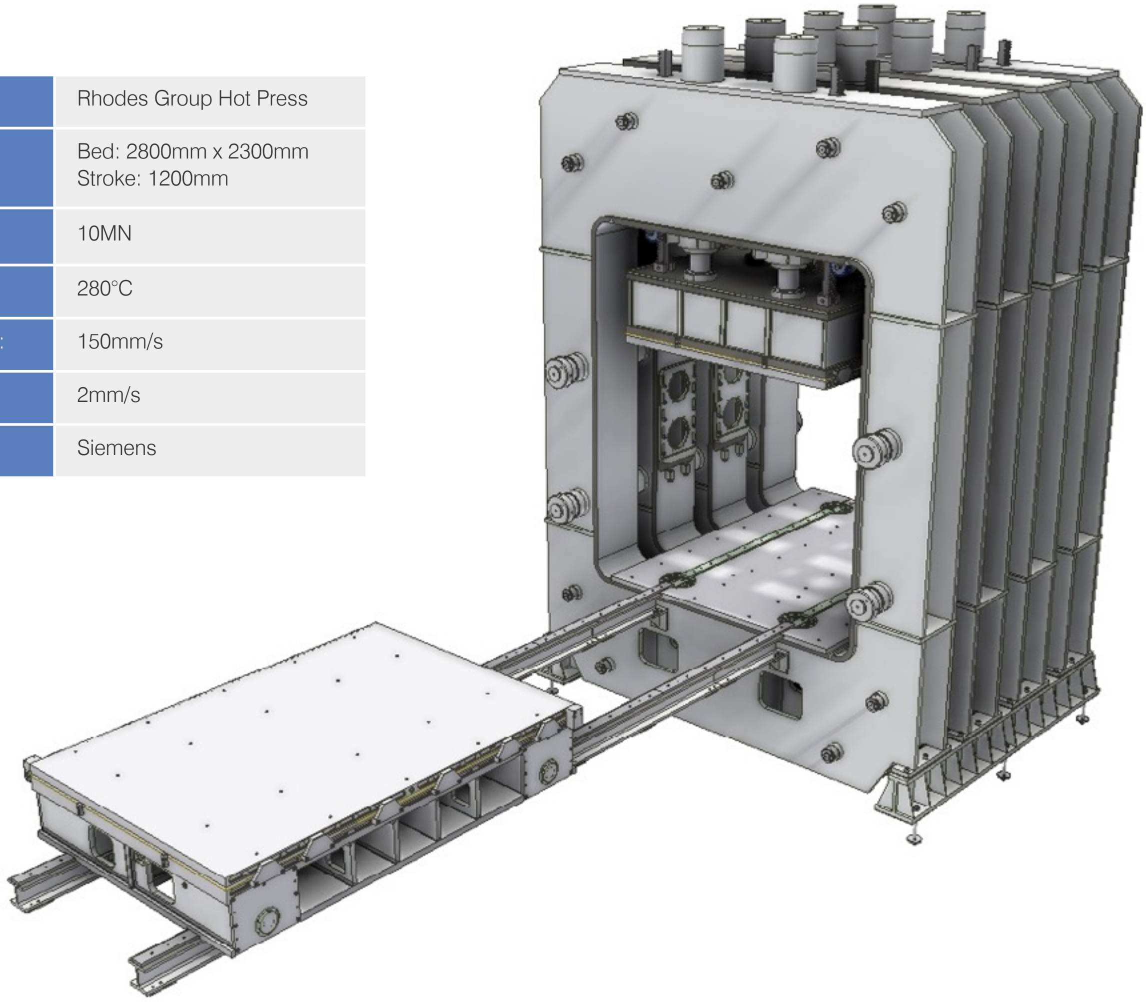
Machine Type:	Rhodes Group Hot Press
Envelope:	Bed: 2800mm x 2300mm Stroke: 1200mm
Load:	10MN
Max Temperature:	280°C
Rapid Travel Speed:	150mm/s
Pressing Speed:	2mm/s
Control System:	Siemens



Langzauner Hot Press

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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

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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

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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

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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.

5-axis CMS Ares and Antares CNC Machining Centres

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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

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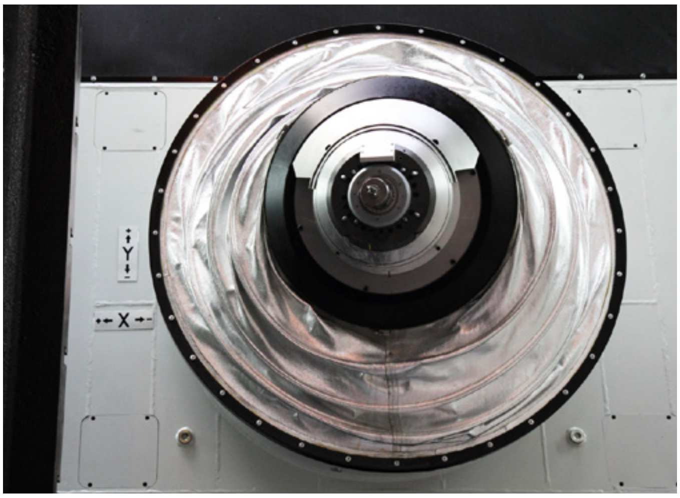
The Ecospeed is designed for high-speed five-axis machining of monolithic aluminium and composite aerostructures.

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.



Type	5-axis high speed machining centre (with PKM head)
X-axis travel	3800mm
Y-axis travel	2500mm
Z-axis travel	Spindle horizontal: 670mm Spindle ±40°: 370mm In A-/B-axis, conical work envelope ±40°
Max spindle speed	30,000rpm
Max spindle torque	83Nm
Max spindle power	120kW
Spindle interface	HSK 63A-63/80
Max acceleration, linear axis	1g
Max acceleration, A/B-axis	685°/sec^2
Max jerk move	50 m/s^3
Coolant delivery type	Dual: HPC and MQL
Max workpiece size	3,800mm x 2,500mm x 370-670mm
Max table load	3,000kg
Additional functionality	Z3 PKM head for rapid 5-axis moves. Specified for wet cutting of carbon fibre reinforced polymer.

Characterisation Equipment Suite

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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.

The new AMRC Lightweight Centre

The two-phased development is expanding the award-winning Factory 2050 with a world-leading press building and lightweight composite centre.

The press building, to be completed by the end of this year, will house a 1,000 tonne press facility. The second phase will house a state of the art lightweight composite centre for advanced composite manufacturing research and development.

The vision is to extend on the AMRC's expertise in carbon fibre composite materials, which is increasingly used in high-value industries such as marine and aerospace because of its high strength and light weight.

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The Queen's Anniversary Prizes
2007