coronet

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Thermoplastic Composites Research Requirements

Gaps in Research & Infrastructure

Thermoplastic Composites Infrastructure Cooperation Network - Coronet

Task 3.3: Identification of Future Research Needs

Final Version After Validation

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1 Introduction

A series of activities have been undertaken in previous tasks in this project to gain an understanding of the current research activities and infrastructure within Europe, and the future research requirements of the industry.

The benchmarking activity in Task 3.1 created a database of thermoplastic composites research, results and infrastructure, to show how thermoplastic composites activities and infrastructures in Europe compare to other materials and regions.

The foresight exercise in task 3.2 used a structured programme of forward looking methods to gain an overall picture of the future of thermoplastic composites, and hence the future direction of research that is needed by the industry. From this we then identified the research infrastructures that are likely to be needed to undertake that research.

This report combines the outputs from the previous two tasks, comparing the future infrastructure and research requirements with the current research and research infrastructure. The initial findings of this series of exercises were prepared in a draft format of this report.

This draft report was then circulated to the 129 original respondents to the foresight survey used in task 3.2, as well as to the task 3.2 workshop participants, inviting each to input additional comments on gaps in research and research infrastructure that had been reported. Their additional comments allowed us to amend the content of the report to better reflect their original thoughts, and also to include some areas of research and infrastructure that were thought to have been missed. These changes have been incorporated into this second, validated report.

Mapping current and needed research activities in this way gives a clear picture of the gaps in Europe's research portfolio and infrastructure, with which the European thermoplastic composites community can effectively plan for the future to maintain its position against accelerating developments in other world regions.

This report forms the output from Task 3.3: Identification of Research Needs, of the Thermoplastic Composites Infrastructure Cooperation Network – Coronet, an Infrastructure Cooperation Network funded by the European Commission.

2 Current and Future Research

Research Needs

This section gives a tabular comparison of the current thermoplastic composite research activities within Europe and its future research requirements, in order to find any gaps in Europe's research portfolio and research infrastructure.

Task 3.1 identified the current research activities being undertaken in Europe, alongside the infrastructure being used, presenting that data in a detailed tabular format under five broad headings:

- Materials
- Processing
- Modelling
- Post-processing
- Testing

Task 3.2 identified the future research requirements of the industry, based on a structured foresight exercise, again reporting those requirements in the form of a detailed table.

Table of Research

These two tables are brought together in this section to allow a direct side-by-side comparison of the current research portfolio and the future research needs within Europe. Under each of these heading and research categories, detailed research needs are presented, alongside the infrastructures that are likely to be required to undertake the research.

This combined table is shown on the subsequent pages.

This table has allowed the major gaps in Europe's research portfolio and research infrastructure to be clearly analysed, and these major gaps are identified in Section 3 of this report.

	Current Research		Future Needs	
	Key research	Infrastructure	Key research	Infrastructure
Materials				
Self-reinforced polymers	SrPP, carbon nano-reinforcement	Fibre-spinning, continuous lamination line (UK, D)	Higher performance polymers, nano-reinforcement	Fibre-spinning, continuous lamination lines, twin-screw extruder
Fluoropolymers	Interfacial chemistry, rapid proce'g, stress-corrosion	Pull-winder (UK)	Processing & application in harsh environments	Pull-winding
LFT	Cost-effective processing, intelligent processing	Injection & compression (D), software, surface treatment	In-line compounding, LFT injection, injection-compression, hybrid moulding	LFT injection and compression cells, hybrid processing cells
Nano-reinforced fibres	Fire retardance, carbon nano-tube reinforc'd SrPP	Twin-screw extruder (UK)	Self-reinforced polymers or other matrices, improved stiffness & temperature	Twin-screw extruders, fibre-spinning
Nanocomposites	Layered silicates, carbon nano-tubes, int'face modification, PE, PA	Twin-screw extruders, analytical equipment	Enhanced fire properties; use with/ without fibres, RTM with C nanotubes	Twin-screw extruders, analytical equipment
Vapour-grown carbon fibres				
Bio-polymers	Cereals, caprolactone, cellulose, veg oils, lignin, polylactide	Processing & analytical equipment	Bio-derived matrices for sustainability; Genetic modification	Bio-chemistry, processing & analytical equipment
Biocompatible polymers	In-vitro and in-vivo assess's, bio-resorbable bone fixings, laser surface modification	Solid-state extrusion (D), laser (UK)	Scale-up, new biocompatible, biodegradable & resorpable polymers and composites;	Fibre spinning, micro CT Bio chemistry, processing and analysis equipment
Recycling	Fibre-spinning, crumb rubber, polyolefins	Centrifugal spinner (UK), compactors, environmental chamber (IRL)	Viable robust recycling, life-cycle analysis, self or nano-reinforced polymers	Pyrolysers, cryogenic grinders, shredding and separation equipment
Novel fibres & fillers	Thermoplastic & steel fibres, phosphate glass	High temp furnace, fibre-drawing, EDX (UK)	Polymeric fibres; weavable titanium and steel fibres	Fibre-spinning, weaving and induction heating
Natural fibres	Cellulose, flax, jute, sisal, hemp, wood, crop waste, high-performance	Fibre charact'n, XPS, TOF-SIMS, harvesting, defibration, treatment (D, DK)	Wood, jute, hemp, sisal and flax, anti-fungal systems	Harvesting, defibration, chemical treatment

	Current Research		Future Needs	
Processing	Key research	Infrastructure	Key research	Infrastructure
Thermoforming, stamping, compression moulding	Optimization, modelling, deformable tooling	High capacity presses, proprietary software (S)	Hybrid forming with local inserts, net-shape, waste reduction; advanced & rapid tooling techniques	High capacity presses, hybrid processing cells, process modelling, injection-compression; cheaper mould systems
Rubber & diaphragm forming	Silicone tools, diaphragm forming, smart blank-holding, modelling	Smart blank-holder (NL), diaphragm forming machine (NL)	New materials, scaling up, diaphragm life, waste reduction	Diaphragm forming machines, process modelling
Filament winding & braiding	Natural fibres, modelling, residual stress, continuous profiles, embedded optical fibres	Filament winders, tow-pregger (PT), braiders (S), ProSimFRT software (D)	New fibres, process optimisation	Filament winders, braiders, software
Injection moulding	Short-fibres, optimization, simulation of fibre orientation	MoldFlow software (IRL)	LFT injection	LFT injection machines
Pultrusion	Fluoro-polymers, rebar, specific profiles	Pull-winder (UK), pultrusion machine (PT)	New fibres e.g. Wood-PP, co-extruded coatings	Pultrusion-extrusion machines
Vacuum processing	Low-cost processing, large parts	Simulation tools (D, NL)	Large-scale heated vacuum consolidation	Tool heating, process control and simulation
Automated tape placement	Optimised tow-placement, simulation	Tape-placement head on 6-axis robot (D), ProSimFRT software (D)	Optimisation of fibre direction, rapid placement, hybrid processing	Tape placement robots, hybrid processing cells
Thermoplastic RTM	PA6, PA12, CBT, scaling-up	Pneumatic injection systems (D, CH)	Scaling-up, development of current PA & PBT systems, new engineering polymer and LCP systems	Pneumatic injection systems, chemical analysis facilities
Heating techniques	Microwave, fast thermal response tools	Dynamic heating & cooling (CH)	Microwave processing & consolidation	Smaller microwave systems
Rotational moulding			Parts with property gradients	
Hybrid processing & sandwich structures	Over-injection moulding, fibre-metal laminates, paper cores	Continuous paper folding (B), prepreg lay-up (D), autoclave (DK)	Synergistic materials and processes, component optimisation, tape-placement, over-injection, thermo-hydro-forming	Hybrid processing cells, hydro-forming equipment

	Current Research		Future Needs	
	Key research	Infrastructure	Key research	Infrastructure
Modelling				
Process modelling & formability	Geometry & property prediction, drape, thermo-forming, tape lay-up, commingled fabrics	TexGen,PamForm (UK), Femap, Ansys (PO), ABAQUS, proprietary software (S)	Part cost reduction via process and cost modelling; integrated enviro-economic modelling; flow & fibre orientation prediction; Hybrid structure analysis; friction models, draping and residual stress analysis	Process modelling & cost modelling software; LCA; enhanced FE with improved post-processing
Component modelling & design	Pressure vessels, design optimization		Component modelling and stress analysis, access to material properties; residual life prediction	Component modelling & stress analysis software, material property databases
Post-processing				
Surface finishing	In-mould decoration/foils, recycling, class A panels, scratch-resist	Membrane forming (UK), double belt press (D), surface characterisation	Class A surfaces, in-mould painting, improved performance, durability	Surface characterisation, chemical analysis, environmental test chambers
Cutting techniques	Laser drilling, water-jet cutting	Laser (UK), water-jet cutter (D)	Rapid, accurate, low-damage techniques	Water-jet cutting machines
Joining & welding	Pipe welding, low energy substrate adhesion, large structures, induction, resistance & ultrasonic welding	Prototype welding machines, XPS, ToF-SIMS, dielectric & induction welding (D), ultrasonic welding (NL)	Rapid, continuous welding techniques, welding of large/complex structures, joint durability; foil welding for different materials	Induction, vibration & laser welding equipment, environmental & mechanical test rigs
Repair	Self-healing materials, durability of bonded repairs		Establishing of standard repair procedures, durability of repairs; microwave repair; self-healing composites	Welding equipment, environmental & mechanical test rigs

	Current Research		Future Needs	
	Key research	Infrastructure	Key research	Infrastructure
Testing				
NDE & health monitoring	Embedded optical fibre sensors, NDT and sensors for pipe-lines	VIBROCAM 5000 data measurem't system (D), proprietary software, holographics (PT)	Embedded sensor fibres, improved in-situ NDE techniques	Sensor fibre placement, data measuring software, NDE equipment
Fire testing	Nano-composites, intumescent & halogen-free retardants	Fire testing rigs (D, PT)	Fire retardance of nano-clays	Twin-screw extruders, fire testing rigs
Impact & ballistics testing	Fibre-metal laminates, toe-caps, aircraft, bomb-blast, automotive crash, pedestrian safety	High speed tensile test, gas gun, falling-weight impact, blast chamber (UK), failure prediction software	Materials with high impact-resistance e.g. self-reinforced polymers	Low & high speed impact test rigs
Fracture testing & damage tolerance	Essential work of fracture of nano-composites, fracture mechanics	Fracture test devices, holographic NDT (PT)	More accurate tools for predicting initiation, interaction and evolution of damage; new failure criteria; damage tolerant materials	
Electrical property testing	Percolation threshold of PP-polyaniline-carbon fibre		Electrical aging	
Environmental, creep and high temperature testing	NVH, stress-corrosion, long-term properties, fatigue, tribology of PEEK-carbon, nano, graphite or PTFE	NVH test rig, stress-corrosion test rig (NL), creep rigs (S), multi-axial fatigue test machines (PT, NL), tribology (D)	Enhanced knowledge of viscoelastic, creep, fatigue, temperature and chemical performance, access to material properties; residual life prediction	Environmental test facilities, material property database; combined enviro-mechanical long-term test facilities

3 Research and Infrastructure Gaps

A detailed comparison of current research and future needs has been undertaken and this has identified a number of gaps in research and infrastructure that need to be addressed by the European thermoplastic composites industry.

These gaps are discussed below under the broad research categories previously used.

Materials

In self-reinforced polymers, work is being conducted in nano-reinforcement of polymer fibres but work is required in higher performance polymers, such as PA and PET etc. It is thought that the necessary infrastructure exists but may need modification for higher-melting temperature polymers.

Allied to this, current research into thermoplastic fibres should be expanded to include other polymers such as PET, PP and PE, although current fibre-spinning facilities should be sufficient. For metallic fibres, enhanced weaving infrastructures are needed. Natural fibres are also a key area of interest and research infrastructures are required for improved harvesting, defibration and anti-fungal treatments.

Biocompatible polymers are an area of large interest, with infrastructure requirements extending from fibre spinning to analysis in order to support future research needs.

Current research into fluoropolymers and bio-polymers seems to match future needs, but Europe appears to lag other regions in bio-compatible systems.

More research is required on fire-retardance of nano-composites and access to nano-scale analytical facilities will be necessary to undertake this work.

For the important topic of materials recycling, a number of technical solutions have been identified but scale-up to larger infrastructures, such as pyrolysers, cryogenic grinders, shredding and separation equipment, is necessary to ensure that these recycling techniques are commercially appropriate.

Processing

Significant research effort was identified thermoforming, stamping and compression moulding. Current research infrastructures in Europe are significant but more investment is required in hybrid processing cells and process models for optimisation and waste reduction, as well as tooling systems. Existing tape placement infrastructure is likely to need modification to reduce lay-up times and for incorporation into hybrid processing cells. Existing rubber and diaphragm forming infrastructure is sufficient for development purposes but larger diaphragm machines will be required to demonstrate industrial relevance.

For LFTs, larger-scale infrastructure such as in-line compounding, LFT injection, injection-compression and hybrid moulding cells will be required.

Research required in filament winding of new fibre systems should be possible on current facilities with minor modifications, although additional infrastructure is needed for the development of continuous filament winding systems and the inclusion of optical fibres. Future needs in pultrusion include work on wood-PP and will therefore require new infrastructures for extrusion and co-extrusion.

In vacuum moulding, current research is attempting to address the forecast issues of large-scale moulding and process simulation, but no major infrastructure gaps have been identified here. For rotational moulding, additional work is expected on functionally graded materials, whilst new microwave infrastructure is required to develop this heating method for a range of processing applications

Finally, thermoplastic RTM has been highlighted as a key area for technological advancement, with new resin systems based on a range of engineering polymers, so it is expected that the number and scale of these facilities will need to increase..

Modelling

In the area of modelling, continued development in process modelling software is required for all major process routes, and detailed and accurate cost models are required to aid part cost reduction. Specific gaps include integrated enviro-economic modelling, flow & fibre orientation prediction, friction models, draping and residual stress life prediction.

Models for design and stress analysis must also be developed and improved, whilst the virtual infrastructure of material property databases must be created and expanded to increase awareness and acceptance.

Post-Processing

In surface finishing, improvements in surface quality and in-mould decoration techniques are required. Durability testing of these surface finishes was identified as an important future research need, but no major infrastructure gaps are foreseen.

In the area of joining, research is ongoing in continuous welding processes and joining of large structures, but more investment in induction welding research equipment in particular may be required.

Repair techniques are under investigation but standard procedures must be developed for industry and, as with surface finishes, extensive durability testing must be conducted. Some significant activity is foreseen in the artea of self-healing materials.

Testing

Research into embedded sensor fibres for health monitoring should be continued, along with the development of nano-clay reinforcement for fire retardance.

Existing impact test facilities are comprehensive and will be useful for evaluating new impact-resistant materials such as self-reinforced polymers.

Significant future research into fracture testing is needed, although no specific research infrastructure requirements have been identified with this, whilst enhanced knowledge of viscoelastic, creep, fatigue, low & high temperature and chemical performance all point to the need for more infrastructure investment in these areas,

Combining the need for significant addition materials data, the requirement for a virtual infrastructure of thermoplastic composite materials property data is again highlighted.

Conclusions

In many cases, Europe's current research and infrastructures match the future requirements. However, a number of gaps have been identified as follows, both in Europe's research portfolio and in its existing research infrastructure:

Research Gaps

- High performance self-reinforced polymers (eg. PA and PET)
- Nano-reinforcement for fire retardance (eg. nano-clays)
- Bio-compatible composites (eg. polysulfone)
- Biocompatible polymers
- Processing and treatment of natural fibres
- Optimisation of thermoforming, stamping and compression moulding
- Filament winding of new fibre systems
- LFT injection processes
- New polymer systems for thermoplastic RTM (eg. engineering polymers and LCP)
- Surface quality and decoration
- Standardised repair procedures and durability testing
- Self-healing materials
- Embedded sensor fibres
- Environmental and long-term testing

Infrastructure Gaps

- Fibre spinning
- Facilities for nano-scale analysis
- Equipment for large-scale economic recycling
- Harvesting, defibration and chemical treatment of natural fibres
- Large diaphragm forming machines
- LFT injection and injection-compression machines
- Rapid tape-placement and hybrid processing cells
- Large injection units for thermoplastic RTM
- Process models and cost models
- Material property databases
- Induction welding