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NPL REPORT MAT 90

Increasing UK competitiveness by enhancing the composite materials regulatory infrastructure

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Head of Materials Science and Engineering

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Increasing UK competitiveness by enhancing the composite materials regulatory infrastructure

OCTOBER 2019

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Contents

Foreword

The UK is recognised, globally, for pioneering the development of advanced composite materials and their deployment into engineering products. The next decade will provide an unprecedented opportunity for the UK to capitalise on its inherent capabilities and build the foundations for growing the composites industrial base from present levels of £2.3bn/y to £12.5bn/y in 2030 (a Compound Annual Growth Rate of 12%). The principal driver for creating these market opportunities is the growing public pressure on Governments to act even more quickly in response to climate change, sustainability and resource efficiency. With transportation accounting for 40% of UK energy use, significant vehicle weight reduction (>25%) is required to reduce the energy demand and thereby assist the UK in achieving its 2027 carbon emission targets.

The UK has a globally competitive aerospace and automotive industry base, and great strides are already being made in exploiting the properties of advanced composites to begin the delivery against these targets. In the aerospace sector these materials have come of age. We, as passengers, notice the benefits of direct flights from the UK to Australia and the significant increases in cabin comfort, without realising that they are the direct result of the widespread adoption of carbon fibre composites in aircraft, such as the latest families of A350 and 787 Dreamliner aircraft. The automotive sector is now beginning to follow suit, building on the UK dominance in the application of advanced composites within the F1 motorsport and luxury car sectors and now beginning to migrate into the wider automotive supply base. The combined progress from the aero and auto sectors towards meeting the transportation emissions and sustainability targets are fundamental to achieving the UK Government' 'Future Mobility' targets.

The growth potential for advanced composite materials is, of course, not entirely restricted to the automotive and aerospace sectors. Significant opportunities exist in the construction, offshore energy and sub-sea exploration and production. In several of these applications high-tech composite materials could be combined with embedded sensors to deliver greater functionality and added value. Improved recyclability of engineering materials and design of components for end-of-life are essential to delivering the projected market growth. Both considerations contribute significantly to the UK Government 'Clean Growth' targets.

The foregoing remarks provide an overview of the major opportunities for UK economic growth if we are successful in creating the appropriate foundations for the UK supply base. The creation of efficient and clear product assurance processes is critical in the successful adoption of new materials into new markets. Recent insightful studies, facilitated by Southampton University and the National Physical Laboratory (NPL), have highlighted the stark differences across the sectors in the level of maturity within the different product assurance and regulatory frameworks when trying to introduce composite solutions. The studies illustrate that there is good reason for the aero and auto sectors (for example) being at the forefront of the adoption of composites. The industries and their global regulatory bodies have worked together to establish a highly sophisticated '21st century' assurance culture, which is understood by all, retains safety at its centre and is now a key enabler in driving the adoption of composites. In contrast, the studies have highlighted clear examples where the regulatory frameworks are a major barrier to progress, especially in blocking the adoption of composites.

It is against this backdrop that the study 'Increasing UK competitiveness by enhancing the composite materials regulatory infrastructure' was carried out by NPL, in partnership with the Composites Leadership Forum and the wider UK composites community. I commend this report to the reader, as it reflects the consolidated views of composites experts drawn from a wide cross section including academics, Research and Technology Organisations (RTOs), Small and Medium Enterprises(SMEs), Original Equipment Manufacturers (OEMs), regulators and UK Government. The report contains important findings and recommendations which require careful consideration as part of the wider plan to attain, or indeed exceed, the UK growth targets for the UK composites industry of £12.5b/y by 2030.

Prof Mike Hinton,

R&T Partnerships, High Value Manufacturing Catapult and World Fellow of ICCM

Endorsements

Composite materials are light, strong and durable and will play an increasingly important role in sustainable transport, energy and infrastructure programmes across the world. Ensuring the regulations codes and standards are fit for the 21st century is a fundamental key to unlocking growth and maximising the potential for UK to take an international lead. The National Composites Centre looks forward to collaborating with NPL to deliver the recommendation of this important report.

Richard Oldfield, Chief Executive Officer, National Composites Centre

This report supports the findings of a parallel study conducted by Composites UK for BSI which focused on the transport sector. One of the key barriers identified in the 2016 UK Composites Strategy was the need for suitable regulations, codes and standards across all sectors to enable new materials to be introduced to existing and new markets. Development of standards is an essential enabler for UK innovators to accelerate the rate of commercialisation of new materials and technologies. Standards underpin our existing trade relationships and will be a lead factor in whether future trade deals are beneficial for UK industries. Thus, it is imperative that suitable standards are in place to enable innovation and allow the UK composites industry to compete in the global market.

The report also identifies the key issue of knowledge and understanding within the industry of where to find and how to apply appropriate standards to material and product development, and subsequent application. Composites UK would support development of the online tool and mentoring scheme proposed. Establishment of an advanced materials assurance centre to coordinate this activity and bring together the regulations, codes and standards community will only help to develop the UK composites sector and increase UK competitiveness.

Dr Sue Halliwell, Operations Manager, Composites UK

BSI welcomes the NPL study on Fibre Reinforced Polymers (FRPs) which highlights the central role that standards play in the adoption of these materials by industry. We look forward to working with NPL and stakeholders from government, industry and academia to deliver the international standards needed by the relevant advanced manufacturing sectors, supporting the UK's ambitions to create leadership in this emerging field.

Dr Katerina Busuttil, Senior Standards Manager, BSI

The ATI supports NPL's report as this seeks to address the needs of the aerospace industry that will enable broader adoption of composite technologies, whilst reducing the cost and time to market. The engagement of a diverse range of stakeholders from across different industries for a standardised approach and building a unique capability will have far reaching impact whilst demonstrating UK plc once again leading the way for Composites.

Alex Hickson, Head of Technology – Structures, Manufacturing & Materials, Aerospace Technology Institute

Executive summary

The UK Composites Strategy forecasted that a greater uptake of composite materials could result in significant economic growth for the UK. The use of composites has the proven potential to make real improvements in the safety, energy efficiency and sustainability of products and systems. They can be applied to a multitude of industry sectors, applications and scenarios, offering unparalleled weight savings due to their exceptional strength and stiffness-to-weight ratios, provide high energy absorption for improved strength and crashworthiness and can create value through opportunities for parts consolidation. They require lower maintenance compared to more traditional materials hence significantly reduce through life costs of finished products.

Despite significant advances in their development, barriers still exist that are slowing, and in some cases preventing, the uptake of these materials and the realisation of the benefits available. These barriers exist in the areas of technology, skills, sustainability and regulation and must be addressed. There are still regulations, (design) codes and standards (RCS) that are not performance-based and explicitly name other, more traditional, materials, preventing the adoption of novel and potentially superior materials for a given application.

This study has taken steps to identify the barriers in place that prevent the adoption of composite materials, and in particular Fibre Reinforced Polymers (FRPs), in advanced manufacturing applications. Consultation with industry, through a deep-dive cross sector workshop, and review of relevant studies published over the last five years, has enabled the identification of a series of actions that must be taken to unlock the current regulatory barriers and increase the use of composite materials across the advanced manufacturing sectors. These include:

- **Accelerate the standardisation and publication of technical documentation**, in the form of guides, specifications, and standards, through a 10-year roadmap that addresses the identified gaps in the RCS infrastructure

- Create a partnership that includes industrial stakeholders and relevant regulatory bodies to **design and implement a digital tool and a mentoring scheme to help industry** adopt and certify novel materials

- Establish an advanced materials assurance centre, to bring together the materials supply chain and regulators and **deliver a central resource for providing access to trusted materials data**, act as the driving force for the realisation in the 10-year roadmap while maintaining the digital tool and mentoring scheme

A ten-year roadmap focusing on eleven key areas is proposed with the aim of translating existing technologies into widely acceptable and usable documentation in the form of guides, specifications and standards as well as developing new technologies where these do not exist. These areas reflect the most immediate needs expressed by industrial stakeholders and will have a direct impact on how composite material products are designed and made. A close collaboration between industrial stakeholders, research organisations and academia is envisaged to realise this roadmap, coordinated by an independent overarching centre.

In addition, the authors propose the development of a digital tool and a mentoring scheme that, acting in tandem, will address the disjointed RCS framework as well as the lack of industry awareness of what is available in terms of agreed specifications, codes and standards and how these connect to the relevant regulations. The introduction of such a digital tool and mentoring scheme will also increase the number of Suitably Qualified and Experienced Personnel (SQEP) that would guide companies, especially SMEs, through the product approval process, saving time and cost. An appropriate partnership that will bring together regulators and industrial stakeholders will steer the initiative through the design and implementation phases, however its longevity will only be guaranteed through ownership by an independent and overarching centre.

Most importantly, it is proposed to establish an overarching advanced materials assurance centre that will bring together regulators and the materials supply chain i.e. materials suppliers, product manufacturers and end-users to specify and qualify materials for several different industry sectors. Equally, the centre will act as the focal point for curating and digitally organising already existing material data enabling ease of access to organisations, while coordinating composite RCS activities between different groups and centres. Ultimately it will assume responsibility for the realisation of the RCS roadmap and ensure longevity of the digital tool and mentoring scheme described above, connecting the RCS infrastructure through ownership and continuous improvement.

1 Introduction

Composite materials result from the macroscopic combination of two or more materials that produces a new material with properties superior to those of the constituents. Reinforced concrete and plywood are good examples of widely used composite materials in everyday life applications. However, in this study the focus is on advanced composite materials, particularly reinforced plastics, where a polymer matrix is reinforced by means of fibres or particulates, though the principles are applicable to ceramic and metal matrix composites.

Reinforced polymer composites find a multitude of engineering applications as they offer unparalleled weight savings due to their exceptional strength and stiffness -to-weight ratios. They also provide high energy absorption for improved strength and crashworthiness and create value through parts consolidation. Finally, they require low maintenance, therefore significantly reduce through life costs. Due to their unique characteristics, composite materials improve safety, reduce greenhouse gases, improve energy efficiency, conserve fuel and reduce waste.

Advanced materials are critical drivers of innovation and competitiveness across a range of industrial sectors and are therefore essential for underpinning key areas of advanced manufacturing across all industry sectors, as well as addressing a range of important societal grand challenges in areas such as mobility and clean growth[1]. To address these grand challenges, manufacturing and future materials are key enablers as *"industries such as aerospace, automotive and others involved in advanced manufacturing calling for more affordable, light-weight composite materials"*[2].

This report is developed from a deep-dive workshop organised by the National Physical Laboratory on behalf of the Composites Leadership Forum, in March 2019, to debate the barriers to and opportunities for the uptake of composite materials to enable growth in the advanced manufacturing sectors. The report is organised in three sections, the **Challenge** where the UK opportunity and the barriers to realisation are presented; the **Industry Views** where the industrial input to regulatory and standardisation barriers are summarised and the **Recommendations** where explicit actions are proposed based on the needs expressed by the industrial stakeholders.

1. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/664563/industrial-strategy-white-paper-web-ready-version.pdf

2. https://www.gov.uk/government/collections/industrial-strategy-challenge-fund-joint-research-and-innovation#manufacturing-and-future-materials

2 The challenge

2.1 THE UK OPPORTUNITY

The 2016 UK Composites Strategy[3] document, following consultation with the UK Composites supply chain, clearly articulated that the UK has the opportunity to grow its 2015 £2.3bn composite product market to £12.5bn by 2030. This is a £10.2bn increase of the composite materials product market over 15 years across eight key industry sectors, namely Aerospace, Defence, Automotive, Rail, Construction, Marine, Oil & Gas and Renewables, having direct impact on

- **safeguarding** existing UK jobs by **maintaining** excellence in Aerospace, Defence and Marine sectors
- **creating** new UK jobs by **capturing** immediate opportunities in Automotive and Renewables sectors and
- **preparing** for future opportunities in Construction, Rail and Oil & Gas

It has been postulated that an additional 50,000 people would need to be employed across all industry sectors to deliver the forecasted product market growth[4].

The UK Composites Strategy is an ongoing collaboration between Government (The Department for Business, Energy and Industrial Strategy, BEIS) and the composites industry through the Composites Leadership Forum (CLF). The CLF is led by industry and was set up in mid-2012 to influence the Government and other stakeholders (incl. industry, research centres and academia); to bring together support for composites and ensure growth and industrial success for the UK. The CLF comprises currently of three Industry Sector Groups and four Working Groups[5].

The stakeholders that help to deliver the strategy are Composites UK, High Value Manufacturing Catapult (HVMC), of which the National Composites Centre (NCC) is a constituent part, British Composites Society (BCS), Institute of Mechanical Engineers (IMechE), Knowledge Transfer Network (KTN), National Physical Laboratory (NPL) and the Future Composites Manufacturing Research Hub.

2.2 BARRIERS TO REALISATION

Compelling evidence has been gathered that *"one of the major inhibitors to the uptake of composites in new sectors is that regulations, codes and standards are often inappropriate for composites. This is because they are both explicitly and implicitly based on named materials, such as steel, and do not permit consideration of composites applications despite the strengths and benefits of the materials in many cases"*[3]. Following the publication of the 2016 UK Composites Strategy, the University of Southampton published a report showing that the major constraint inhibiting the growth / use of composite materials in these industries is the regulation of new materials[6]. Consultation and in-depth research on the regulations in each sector was used to reach this conclusion. The report went on to recommend *"that a single Government department takes overall responsibility, alongside the Composites Leadership Forum (CLF), to appoint a project team to produce and fund a project plan for adaptation of a centralised organisation to develop, store and disseminate performance codes, standards and best practice for the use of all sectors"*[6].

3. https://compositesuk.co.uk/system/files/documents/Strategy%20final%20version_1.pdf
4. https://www.iom3.org/materials-world-magazine/feature/2019/may/10/rise-composites
5. https://compositesuk.co.uk/leadership-forum/about-clf
6. https://compositesuk.co.uk/system/files/documents/Modernising%20Composite%20Materials%20Regulations-%20April%202017.pdf

Further to the studies above, a report produced by the US National Institute of Standards and Technology (NIST)[7] highlighted that the three most important actions in order to overcome barriers for adoption of composites in sustainable infrastructure are: (a) the development of durability standards as well as predictive models and data to support them; (b) the creation of a clearinghouse to gather, curate and disseminate this information for infrastructure applications and; (c) enhanced education and training materials fed into university and industrial curricula for use in composites training and certification programs.

Finally, the UK's National Physical Laboratory (NPL) conducted an industry survey[8] that indicated the need for increasing the awareness of the existing Regulations, Codes and Standards (RCS) infrastructure while continuing to address gaps in it. It was also apparent that addressing the skills shortage through training in all educational and vocational levels will result in appropriate use of the RCS and increase productivity.

7. https://www.nist.gov/publications/road-mapping-workshop-report-overcoming-barriers-adoption-composites-sustainable

8. G D Sims, M R L Gower, M King, W R Broughton, Assessment of barriers to and opportunities for the uptake of composite materials to enable growth for UK Advanced Manufacturing Sectors - Summary, NPL Report MAT 88

3 Industry views

Industrial views and requirements were collated through the cross-sector workshop in March 2019, organised by NPL on behalf of the Composites Leadership Forum and hosted by BEIS. This deep-dive meeting was attended by 44 technical experts and relevant business leaders to identify in more detail the specific needs across sectors. The individual responses received, presented in Appendix 1, were used to map out each sector's views on three main topics:

1. Missing methods, codes and standards along a generic product approval case that would support faster and more robust composite product verification
2. Need for and feasibility of an interactive tool to navigate the regulations, codes and standards infrastructure in each industry sector
3. Need and appetite for a shared composite materials database

3.1 MISSING METHODS, CODES AND STANDARDS

Aerospace

Generally, the regulatory framework in the Aerospace (Civil) sector is performance-based and favourable to the introduction and use of new materials[6], specifically composites, in primary as well as secondary structures. As such there is no need for an outright change. In contrast, design codes in most cases as they stand need to be more performance-based or even prescriptive to allow for innovation and introduction of new materials and methods. The Composite Materials Handbook (CMH-17)[9] defines high-level design approaches, but more non-proprietary design guidelines will boost innovation from SMEs giving them more freedom and confidence to explore novel designs.

Companies from the Aerospace sector that attended the workshop stated having an average awareness of RCS and were generally involved in developing new standards aimed at their specific needs, while there was consensus that the available composites related training is not sufficient at all levels and in particular at a technology manager and engineer level.

Moreover it was discussed amongst participants that the building block approach is largely adopted by the industry to develop composite structures and components, where confidence is built progressively by increasing the complexity of testing and simulation from materials at the constituents' level, lamina and laminates, structural details and components, to full-scale structures. Although simulation and virtual testing is used, most of the building block approach is realised through physical tests which is particularly time consuming especially at the Materials and the Full Structure validation level. A reduction in time could be achieved by increasing the amount of virtual methods employed as well as the number of available qualified materials for aerospace use for which properties are openly available. This could reduce the need for coupon testing when data can be obtained by virtual tests.

9 https://www.cmh17.org/

Along a product's validation chain[10] where defined codes, specifications and standards exist from the material constituent level all the way to final product approval, with an overarching theme of non-destructive evaluation, maintenance and repair, there are certain areas that require immediate attention, and these were identified by the workshop participants as:

(a) thermal and electrical conductivity standards;

(b) joining of similar and dissimilar materials specifications;

(c) validated methods for high strain rate properties and fracture toughness;

(d) standards for thermoplastics, short-fibre composites, 3D-composites and nano materials;

(e) validated standards for quantifying processing parameters;

(f) validated virtual methods;

(g) methods for accurate volume fraction evaluation;

(h) qualified NDT techniques;

(i) generic repair specifications and

(j) guidance on fastener free repair, repair of non-crimp and woven fabrics.

Defence

The general approach for the UK Defence sector and in particular the military aircraft is to use an assurance philosophy that shares commonalities with civil design codes, specifications and standards and add on specific military requirements as needed i.e. blast ballistic attack etc. Many of the particular requirements are controlled by Defence Standards (Def Stans®) published by the Ministry of Defence (MoD)[11].

Companies in the Defence sector that were present in the workshop declared having a below average RCS awareness although they were largely involved in developing new standards. There was also agreement that for the sector the available composites related training is insufficient at all levels i.e. technician, engineer and technology manager level.

Like civil Aerospace, the building block approach is largely adopted by the sector to develop composite structures and components, where confidence is built progressively by increasing the complexity of testing and simulation.

Simulation is performed more extensively at the higher levels of the building block approach (i.e. sub-components, components and full structure) which are also considered as the most time consuming during the product validation process. It was suggested by the participant companies that a reduction in time could be achieved by shrinking the middle of the certification pyramid[12] and validating / standardising virtual qualification methods.

10. https://compositesuk.co.uk/system/files/documents/review_of_composites_standardisation_activities.pdf

11. https://www.gov.uk/guidance/uk-defence-standardization

12. Rouchon, J. (1990) Certification of large airplane composite structures, recent progress and new trends in compliance philosophy. ICAS. Stockholm, Sweden, CEAT. p. 1439-1447

Furthermore it was noted that the current certification pyramid which is applicable to structural integrity would also need to be extended to other load environments. For example, there is no coherent approach linking fire response in the laboratory to the fire response of the in-service system. This, in conjunction with the creation of standards for virtual assurance, which will reduce the need for coupon testing where data can be obtained by virtual tests, could help maximise the use of composites.

The areas along a product's validation chain, identified by the workshops participants, needing immediate attention:

(a) standards for 3D-composites and nano materials;

(b) specifications and standards for fire properties;

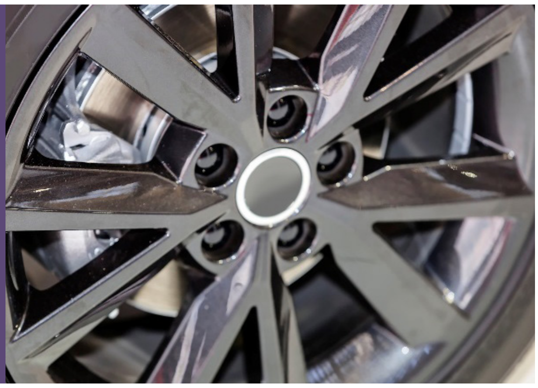
(c) validated virtual methods;

(d) qualified NDT techniques;

(e) standards for quantifying thermal decomposition and

(f) Computerized Tomography for large parts.

Automotive



The automotive industry has two very discrete sectors, the large-volume sector and the high-performance, specialist sector producing vehicles in small numbers. The large volume sector is highly sensitive to the price of materials and the cost of capital plant to process them at the pace needed to satisfy the economic production rates. These pressures have traditionally limited innovation in materials selection. Niche and small volume vehicle production have different design and product introduction cycle times, resulting in a greater freedom to introduce new production methods and materials.

Regulation in the Automotive sector is performance-based and therefore more open to the use of composite materials[6]. To determine whether materials and structures are suitable for use, collision testing of the fully built vehicle is conducted. This approach (i.e. strength, stiffness and energy absorption of full-scale structure) is not prescriptive in demanding or eliminating any materials for use as any type of material must satisfy the same testing regime.

Participants from the Automotive sector in the workshop declared having a below average RCS awareness, although, half of the contributors were involved in developing new standards. Similarly, there was agreement that for the sector the available composites related training is insufficient at all levels, particularly at technician and technology manager level.

Participants indicated that unlike Aerospace, the building block approach and especially the middle part of it (structural details, components etc.) has little applicability in the Automotive sector where the most common approach is to perform testing at a material level, mainly to understand the performance of individual materials, and then undertake collision testing on the full-scale vehicle to obtain certification and prove compliance to structural integrity regulations. Consequently, the

Material and Full Structure level tests were noted as the most time consuming. It was articulated that a reduction in time can be achieved by having in place agreed standards for different materials, including joining and multi-materials, formats and structures with data that substantiate these choices as well as validated modelling tools and appropriate materials data to undertake virtual validation exercises, hence reducing the time and cost of the full-scale collision testing.

Along a product's validation chain the following areas have been identified by the participating companies as needing immediate attention:

(a) validated virtual methods;

(b) specification for hybrid material systems (e.g., metal-composite);

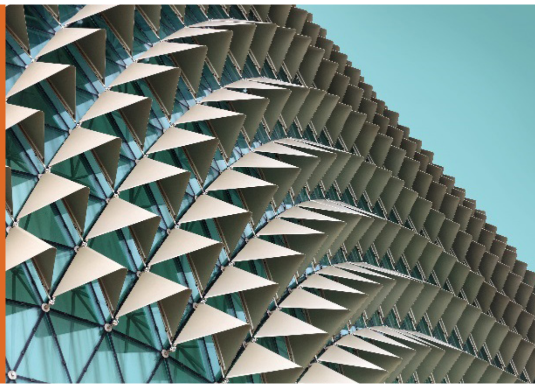
(c) validated damage tolerance approach for road vehicle structures;

(d) qualified NDT techniques;

(e) crash performance standards and

(f) generic repair approaches to support continuous maintenance.

Infrastructure[13]



At a high-level, regulation in the sector regarding material usage is performance-based[6]. However, the guidance on how these broad performance criteria are to be met using composites is missing compared to more traditional materials. The currently underway development and implementation of the composites-specific Eurocode will immensely assist in the broader use of composites across the sector. Initiatives like the one leading to the publication of "Design guidance for strengthening concrete structures using fibre composite material"[14] and more recently of "Fibre-reinforced polymer bridges – guidance for designers"[15] are steps in the right direction for providing the toolset for structural engineers to consider composites.

Participants from the Infrastructure sector in the workshop declared having a below average RCS awareness with half of the contributors involved in developing new standards. Similarly, there was agreement that for the sector the available composites related training is well covered apart from at technician level.

Unlike most other sectors analysed, the building block approach is not employed at all in the Infrastructure sector, as clearly indicated during the workshop. Instead, approval is obtained on a case-by-case assessment by the Head of Profession. The use of simulation and virtual methods is very limited, and the main efforts are concentrated on full-scale physical testing to prove structural integrity. It is therefore not a surprise that the highest levels of the pyramid are considered as the most time consuming. It was indicated that a national database of composites, that lists specific properties, which is easily accessible amongst relevant parties, would benefit the sector and increase composites usage. Further development of design guidance documents and technical mentoring from experienced and qualified professionals during the approval process would also help.

13. Infrastructure encompasses construction (buildings) as well as railway and highway infrastructure

14. https://www.thenbs.com/PublicationIndex/documents/details?Pub=CS&DocID=305394

15. https://www.ciria.org/ItemDetail?iProductCode=C779F&Category=FREEPUBS&WebsiteKey=3f18c87a-d62b-4eca-8ef4-9b09309c1c91

Along a product's validation chain the following areas have been identified, by the participating companies as needing immediate attention:

(a) validated virtual methods;

(b) specification for nano-enhanced materials and guidance for use;

(c) validated damage tolerance and defect criticality approaches for civil engineering structures;

(d) qualified NDT techniques and

(e) standards suitable for thick composites.

Energy

There was focussed representation from the Oil & Gas sector at the workshop and so, this section will primarily refer to applications relevant to this. Thus, for the Oil & Gas sector the MODU Code[16] explicitly permits the use of steel but provides national administrators with the power to authorise any other material with similar performance but without specifying any means of compliance. Outside of this code, the regulatory framework is generally performance-based[6]. There are several international[17,18] as well as industry standards[19,20] specifying the use of composites, however an increasing number of those, together with documentation that detail acceptable means of compliance to the MODU Code, will benefit the sector.

Participants in the workshop from the Oil & Gas sector declared having an above average RCS awareness with two-thirds of the contributors involved in developing new standards. There was also consensus that, the available composites related training is poorly covered, especially at the technician level. Following best practice from other sectors, the building block approach has been adopted by the Oil & Gas sector. In addition, and in the specific case for engineered repairs, type approval is normally obtained through (i.e. Lloyd's / DNV GL) classification societies.

The participating companies indicated that the use of simulation and virtual methods is becoming widespread above the materials level in the certification pyramid, aiming to further reduce time and cost. It was indicated that introducing validated virtual methods and non-destructive evaluation techniques, alongside guidance on long-term environmental performance prediction and more detailed end-product specifications of acceptable performance, will reduce the time to final product approval considerably.

16. Code for the Construction and Equipment of Mobile Offshore Drilling Units (MODU Code) 2009 (Available from https://www.dandybooksellers.com/acatalog/2009_MODU_Code_2010_Edition.html)

17. ISO 14692-2:2017 Petroleum and natural gas industries -- Glass-reinforced plastics (GRP) piping -- Part 2: Qualification and manufacture

18.ISO 24817:2015 Petroleum, petrochemical and natural gas industries -- Composite repairs for pipework -- Qualification and design, installation, testing and inspection

19.DNVGL-ST-C501 Composite components

20. DNVGL-ST-F119 Thermoplastic composite pipes

Along a product's validation chain the following areas have been identified by the participants as needing immediate attention:

(a) standards for non-flat composite laminates;

(b) guidance on adhesive bonding;

(c) validated damage tolerance and defect criticality approaches;

(d) validated and qualified NDT techniques;

(e) guidance on generic repair and

(f) life extension methodologies of in-service repairs.

Marine

The position paper "Modernising composite materials regulations" [6] published in 2017 has highlighted that the regulatory framework in the Marine sector is prescriptive, in its various requirements for the use of steel. In addition, fire protection and combustibility are the key drivers for choosing a material since much of the regulatory framework focusses on ability of the vessel to be able to withstand a fire to an extent or a period of time. Importantly, the SOLAS[21] regime provides some flexibility and describes some broad equivalence terms of allowed materials.

Participants from the Marine sector in the workshop indicated having an above average RCS awareness with two-thirds of the contributors involved in developing new standards. There was also consensus that, for the sector, the available composites related training is not well covered especially at technician level. It was indicated that the use of a building block approach depends on the vessel under design, e.g. small dinghies would be treated very differently to large ships under SOLAS regulations. Generally, the concept of the building block approach is applied, but it is less structured when compared to the Aerospace sector. Furthermore, participating representatives noted that simulation and virtual methods are primarily used at the middle parts of the validation chain while only physical testing is considered at the full-scale level. It was suggested that by introducing standardised materials for appropriate applications while sharing test data from these materials across the industry, as well as having RCS that are specific for Composites (i.e. drop the guidelines that ask for equivalence to steel) will reduce the time to final product approval considerably.

Along a product's validation chain the following areas have been identified by the participants as needing immediate attention:

(a) standard set of material properties;

(b) guidance on adhesive bonding;

(c) validated damage tolerance and defect criticality approaches;

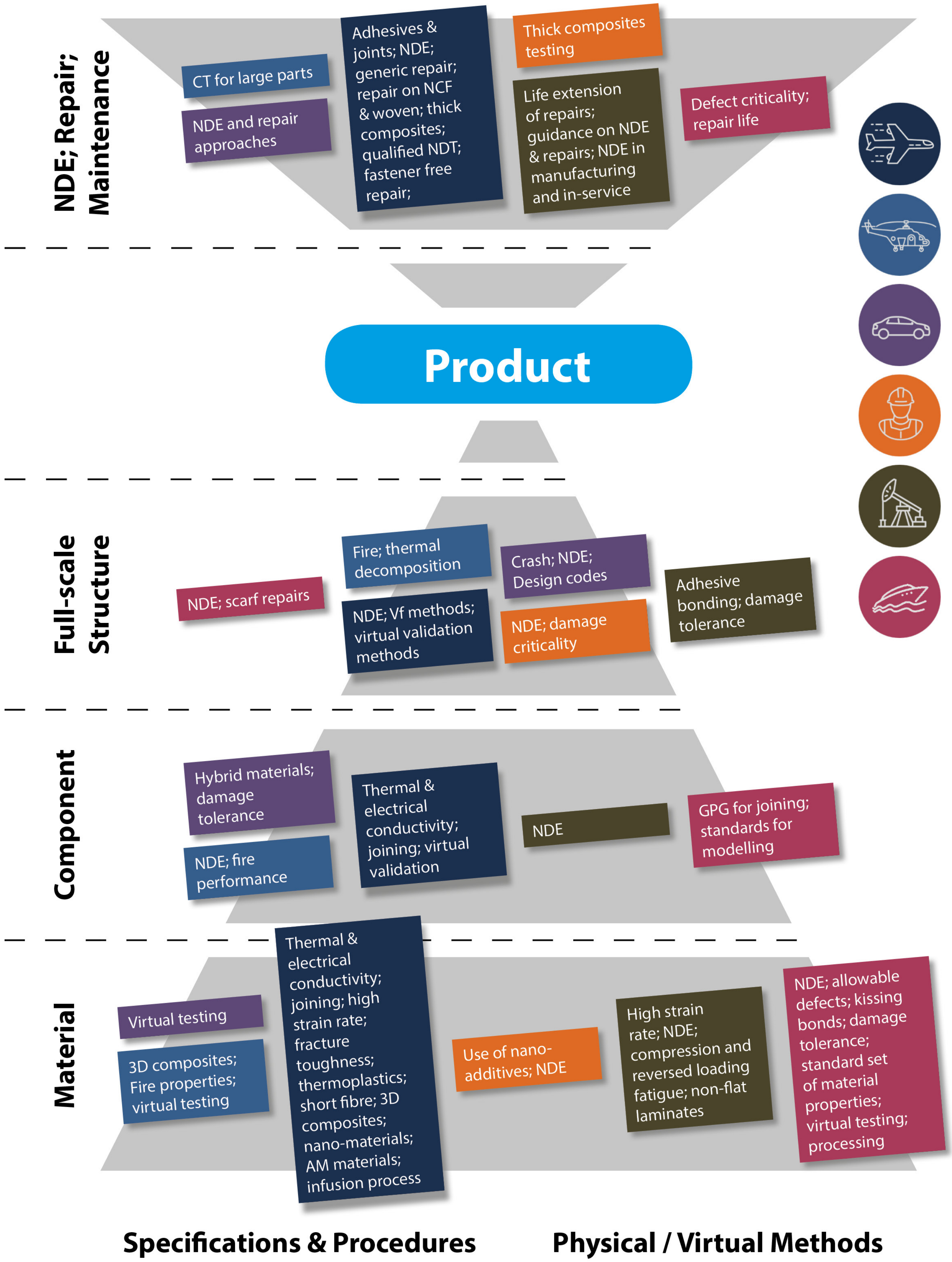
(d) validated and qualified NDT techniques;

(e) validated simulation and virtual testing tools and methodologies and

(f) guidance on generic repair and life assessment of in-service repairs.

21. International Convention for the Safety of Life at Sea (SOLAS), 1974

Key missing methods, specifications and procedures as indicated by the workshop participants



3.2 NAVIGATION OF THE REGULATIONS, CODES AND STANDARDS INFRASTRUCTURE

Apart from the Aerospace and Marine sectors, workshop participants indicated that navigating the required and available Regulations, Codes and Standards for approving a product is particularly difficult. Furthermore, companies within the Defence, Automotive, Infrastructure and Energy (Oil & Gas) sectors receive little or no support related to practical aspects of the product approval process from agencies and/or classification societies. Specifically, in the question, what is the level of support related to practical aspects of the product approval process you currently receive from agencies and/or classification societies in your industry sector? Scores from participating individuals of the latter four sectors were between 1 and 1.5 (where 1 is low and 5 is high).

Across the industry sectors there was agreement that an interactive tool providing a clear link between regulations, available design codes, specifications and standards, alongside a mentoring scheme to offer guidance, will benefit both the individual organisations and the respective industry sectors. In the question, a virtual tool for providing a clear linkage between regulations, design codes, specifications and standards will benefit (a) your industry sector and (b) your organisation? Average scores across industry sectors were 3.9 and 3.8 out of 5, respectively. There was also consensus that for such an initiative to work and a tool to be implemented the relevant regulators would need to be engaged early in the process.

The type of backing that industry is seeking to unlock the potential of composites is generic support as opposed to Original Equipment Manufacturer (OEM) specific with clear technical guidance through the certification process by Suitably Qualified and Experienced Personnel (SQEP). Such guidance should start from general awareness of the certification process and availability of appropriate documentation and expand to cover technical support on how to meet the standards. Furthermore, emphasis should be placed on composite Materials & Processes (M&P) training for non-composites experts to enhance understanding and knowledge by the relevant bodies (i.e. classification societies, agencies), since composites specific knowledge is still limited. It has been suggested that by establishing a single focal point where independent advice, in-line with the regulators' requirements, could be provided to navigate the regulatory framework would save companies time and cost. Some of the specific suggestions made by participating individuals were:

"RCS for new manufacturing processes that require in process verification"

"Guidance through the certification process by SQEP"

"A single place where independent advice could be provided on NDE and the way through the regulation procedure"

"Working with regulators in a form of mentoring system similar, but not so rigorous as the Nuclear industry, would save companies time and cost"

3.3 SHARED COMPOSITE MATERIALS DATA

The consulted industrialists, except for those in the Oil & Gas sector, overwhelmingly believe that a shared composite materials database will benefit their industry sector as well as their individual companies. More specifically, in the question, do you believe that a shared composite materials database will benefit (a) your industry sector and (b) your organisation? Responding participants from the Aerospace and Defence sectors replied positively (scores 4.3 out of 5) for both the industry sector and their organisation. Participants from the Automotive and Infrastructure sectors believed that the benefit will be greater for the industry (scores >4.6 out of 5) than their organisation, while those from the Marine sector agreed equally to both sections of the question (score 3.6 out of 5).

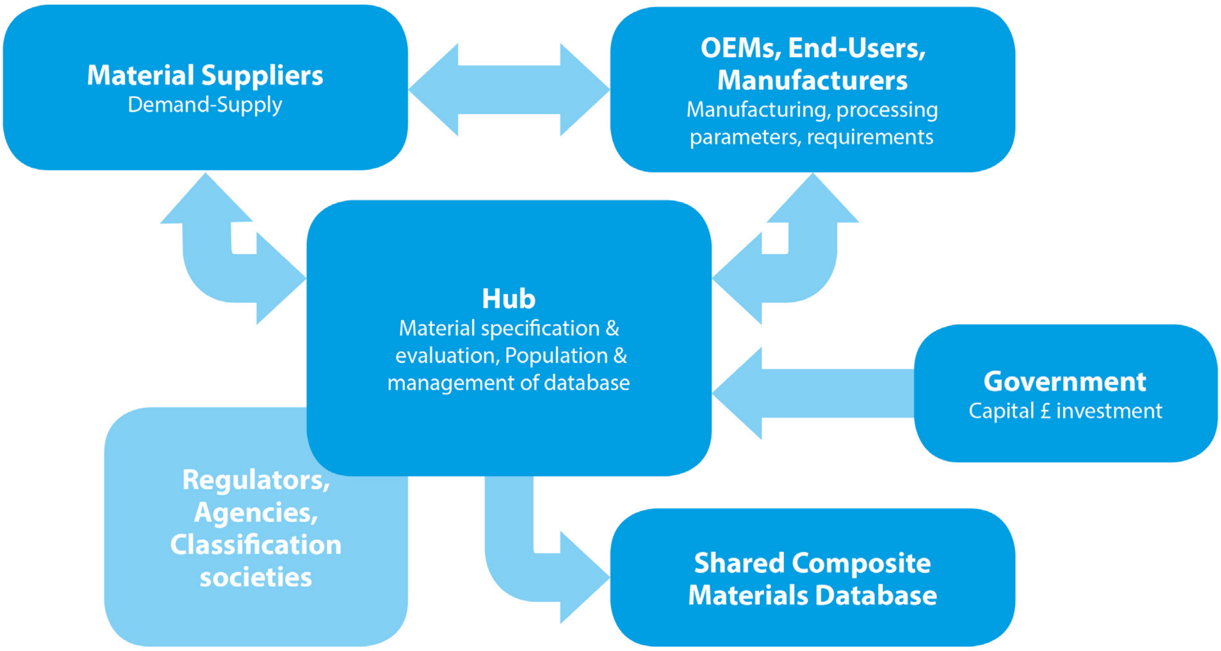
It was noted by the workshop participants that such a database should include non-design specific data, both mechanical and physico-chemical data that could be used to derive design allowables. In addition, high strain rate, damage tolerance, fatigue and durability data on common laminates (e.g. with different resins, and fabrics) will immensely assist companies to make an informed choice against their product definition. Specifically, the need for a central repository of durability data for composite materials has also been highlighted in a recent report by NIST[7].

However, several challenges exist in both generating and using common materials data, even within an industry sector. In Oil & Gas there is often "*little commonality between equipment manufacturers to need a common data set*". In addition, material selection, manufacturing methods as well as intellectual property rights in the generated test data are market differentiators, making it difficult at present to consider sharing data.

In fact, the most common challenge across all industry sectors is related to intellectual property rights as there is often IP, related to a material, resting with the product manufacturer if they have contributed significantly towards the development of it to fit their application. The other most common challenge is related to the cost of generating the data as well as the cost of its (database) support and maintenance. Still, industrial stakeholders believe that shared composite materials data "*would benefit technology development and force price competition*".

A majority of 80% of the responding participants indicated that a possible cost sharing model where all stakeholders contribute a portion to the overall cost in order to have access to the common dataset, could be a viable solution for the UK providing a sound enterprise model is put in place.

Possible model for sharing valuable, traceable data



4 Recommendations

To further unlock the potential of composite materials and exponentially increase their uptake by the UK advanced manufacturing industry sectors the following immediate actions are recommended:

ACCELERATE the standardisation and publication of technical documentation, in the form of guides, specifications, and standards, that address the identified gaps in the RCS infrastructure

The focus should be on the eleven key areas that present the greatest overlap between the different industry sectors and identified during the workshop. A 10-year roadmap of activities for these key focus areas is proposed. All focus areas listed are appropriate for all industry sectors even though the readiness level varies with sector.

There are currently various activities within the UK and European composites landscape that partially address the technology gaps that underpin the RCS needs of the different industry sectors. What is missing is a coordinating, focal point that would have an oversight of these activities and connect the various working groups and research activities aiming to direct effort accordingly; to transfer knowledge across industry sectors and interact closely with the standards development framework.

The CLF working group on Regulations, Codes and Standards partially fulfils the above role, however with no power to assign budget or direct efforts it is difficult to have more than a shorter-term significant impact. It has encouraged relevant work at several Universities and UK research and standards organisations like NPL, NCC and BSI where there is alignment. An advanced materials assurance centre, as is proposed later in this report could be the focal point, ultimately accountable for the realisation of the roadmap, reporting back to the CLF RCS working group on progress.

Roadmap for addressing key missing codes, specifications and standards in the RCS infrastructure

FOCUS AREA		SHORT-TERM (2019 → 2021)	MEDIUM-TERM (2021 → 2024)	LONG-TERM (2024 → 2028)
MATERIALS	**Nano-, graphene-enhanced new preforms**	Research and review applicability of evaluation methods and standards against requirements for thermoplastics, heavier weight preforms and upcoming advanced materials developments	Devise comprehensive and informed methodology for transferring and/or adapting existing standards and measurement methods to the qualification of new materials	Develop specific methods and standards that would allow evaluation of new materials and formats, enabling their incorporation in the "Design, Make, Test" process
MATERIALS	**Thermoplastics**		Provide clear and concise guidance as to which standards, methods, specifications and codes can be directly applied to thermoplastic materials	
MATERIALS	**Strain Rate Performance**	Define boundaries of current physical measurement methods to accurately derive properties appropriate for intermediate and high strain rate applications	Derive appropriate test methodologies and deliver round robin exercises to validate findings	Publish robust, acceptable methods and standards for measuring high strain rate (i.e., crash) properties
PROCESSING	**Infusion & OoA Processes**	Deliver second world-wide benchmarking exercises on compressibility and through-thickness permeability	Derive common methodologies for all major processing parameters (permeability x-y-z, compressibility, drapeability, tackiness)	Publish robust, acceptable methods and standards for measuring processing characteristics (permeability, compressibility, drapeability, tackiness)
STRUCTURAL PERFORMANCE	**Joining**	Review qualified methods and provide guidance for adhesively bonded and bolted joining techniques	Develop and validate methods for same and multi-material joining	Publish proven and commonly accepted technical procedures for assessing durability and life assessment of bonded joints
NON-STRUCTURAL PERFORMANCE	**Fire**	Enhance understanding of the underpinning physics of the fire environment linked to the key attributes of the system	Ensure fire, smoke and toxicity standards are fit for purpose	Establish a coherent philosophy, in the form of a building block approach, to link fire response in the lab to the fire response of the in-service system
NON-STRUCTURAL PERFORMANCE	**Conductivity**	Review suitability of existing methods for both electrical and thermal conductivity measurements liaising with the relevant TWA in VAMAS	Publish technical guidance on appropriate methodology and available standards for conductivity measurements (electrical, thermal)	
VIRTUAL EVALUATION	**Validation of simulation tools and approaches**	Develop and validate virtual test methodologies focusing on the middle and top of the certification pyramid		Standardise virtual processes for allowables, testing and validation aiming to reduce physical testing and time to product approval
NON-DESTRUCTIVE EVALUATION	**Non-destructive Testing**	Qualify existing NDT methods appropriate for each industry/material/application combination	Develop new NDT methods for honeycomb and integrated structures	Standardise procedures and NDT methods for composites applicable across industry sectors exercised by accredited practitioners
NON-DESTRUCTIVE EVALUATION	**Defect Criticality & Damage Tolerance**	Define sector specific requirements for damage tolerance	Issue comprehensive guidance on defect criticality based on NDE data and in-service conditions to inform repair approach and design	Develop simple and closed-loop go/no go systems to enable rapid diagnosis and decision making on standard structural features
MAINTENANCE	**Repair**	Customise available standard repair methods and provide guidance on generic repair approaches	Develop technology for repairing different fabric technologies i.e. NCF, woven, braided	Establish procedures for assessing the robustness and longevity of repairs incl. life extension of repairs in service

CREATE a partnership, including industrial stakeholders and related regulators, to design and implement a digital tool alongside a mentoring scheme that will provide guidance and a clear link between Regulations, Codes and Standards (RCS) along a product's approval case relevant to each industry sector

The digital tool and corresponding mentoring scheme will aim to address the issues of: (a) **disjointed RCS framework**, where a significant number of standards, specifications and design codes exist, but their connection to regulations is not necessarily clear; (b) **lack of awareness of what is available** in terms of agreed specifications, standards and codes that enable validation and subsequent certification of a product; and (c) **lack of Suitably Qualified and Experienced Personnel (SQEP)** that would guide companies along a product's validation chain.

A company, from any sector, that wishes to develop a product using composite materials, but is unclear on how to go about validating and certifying its product, could use the digital tool and take advantage of the mentoring scheme, as already partly demonstrated by the ***Materials***Solutions[22] tool.

The digital tool will allow for selection of standards, specifications and design codes, where these are available, but most importantly link these to the relevant regulations in each industry sector. Thus, it will provide a simple, single place for a business to navigate the RCS infrastructure saving time and cost. The corresponding mentoring scheme through knowledgeable and experienced practitioners will assist companies, specially SMEs, to navigate the RCS framework and provide guidance through the product validation process.

The proposed tool will be a web- and app-based solution, hence widely and easily accessible by interested companies. Mentoring will be provided by SQEP and the pairing between an interested company (mentee) and the mentor will be performed via the digital tool. Because each sector's regulator, supported by the appropriate supply chain, will be involved in the process of designing the tool, it is expected that the path to product validation will be drawn clearly at the beginning of the process, resulting in increased productivity.

To the best of our knowledge there is not currently any similar offering specifically for composite materials in the UK or elsewhere. Some classification societies offer consultancy through the certification process, however, as sometimes they would also certify as well as perform physical validation testing, some conflict of interest could arise. The recommended digital tool and mentoring scheme is envisaged to operate independently from any regulator and/or certification body as well as any test-house.

To safeguard the longevity and continuous improvement of the digital tool and the mentoring scheme, it is important that the initiative is self-sustaining through company membership (e.g. drop-in / pay-as-you-go), documentation licenced purchasing and mentoring fees.

An initial cost for the design, implementation as well as management for the delivery of the tool and scheme would need to be shared between relevant stakeholders (i.e. regulators, Government departments, industry, etc.). The design and implementation phases will include all process mapping and identification of appropriate documents to be referenced in the tool. Equally, the processes for assessing, recruiting and assigning mentors would be thoroughly defined.

Success would be measured by the uptake of the tool and mentoring scheme, through use, and by monitoring and quantifying the reductions in time and cost to approve composite products, thus enabling industry to further consider using composites. Interested companies would be reached through the regulators / certification agencies, Composites UK, Composites Leadership Forum, social media (e.g. LinkedIn, Twitter), website etc.

Building on the strong elements of ***Materials***Solutions and drawing experiences from several schemes addressing similar challenges in other business areas would enable building a very robust digital tool and complementary mentoring scheme. Some notable existing or retired schemes are:

MaterialsSolutions[22] in its current form "*provides answers to problems associated with materials measurement, testing, standards, design, usage and characterisation*." Although currently not kept up-

22. http://www.materialssolutions.info

to-date, in its conception it included a number of modules: Virtual Consultant, Measurement Advice and Engineering Solver as well as dedicated space for the user to find information on completed composite materials related projects.

BSI's Compliance Navigator[23] which is a simple way to "*manage regulatory information for Medical Device and In Vitro Diagnostic products with UK and EU requirements, helping businesses to get to market faster*."

Late Life Planning Portal (L2P2)[24] that "*has been designed to support the North Sea oil and gas industry in the planning and execution of late life and decommissioning projects*." The portal provides a "*single access point for knowledge sharing and cross-sector learning*," bringing the regulators, operators and supply chain together, hence creating the supportive environment required by the decommissioning industry.

Although currently not live, the Mentoring in Nuclear Decommissioning Industry Scheme[25] by the Nuclear Decommissioning Authority connected business mentors to UK-based SMEs having an involvement or aspiring to work in the nuclear decommission. Business mentors helped the SMEs "*develop their ideas for growth by sharing their skills, expertise, experience and contacts*." They also provided help to "*small businesses to navigate through the maze of nuclear decommissioning opportunities*."

ESTABLISH, with relevant stakeholders, an advanced materials assurance centre, transferring knowledge from existing international centres while using international standards as the platform for a universally accepted standard set of material properties

The biggest barrier to more widespread use of composites is the lack of material standardisation and the fact that there is not sufficient reliable design data and specifications widely available, which often forces designers to use other materials [26,27]. Further, fast paced product developments mean that there is lack of time and/or budget to conduct a full qualification test programme and generate data for a composite material. An advanced materials assurance centre would aim to overcome these issues by bringing together regulators, materials suppliers and manufacturers to specify and qualify materials for a number of different industry sectors, borrowing best practices from the successful example of the US National Centre for Advanced Materials Performance (NCAMP)[28] in Aerospace. It would also act as the focal point for curating and digitally organising already existing material data enabling ease of access to organisations, while coordinating composite RCS activities between different groups and centres.

This new focal point for composites RCS and material qualification could be approached by any company of any size that wishes to produce and certify a product out of composite materials. Particularly SMEs often do not have the resources either in the form of experienced and qualified personnel or budget to navigate the RCS infrastructure and ultimately qualify a material for use in their product. These companies would often prefer to choose an already qualified material and receive guidance on how to meet the regulatory requirements using appropriate design codes and standards. Even larger organisations would prefer to focus on application, process specific design and validation activities rather than qualifying materials. A membership enterprise model would have to be established for companies to share the cost of material qualification and subsequently share the wealth of technical data that could be organised in the form of a smart database.

23. https://compliancenavigator.bsigroup.com
24. https://decomnorthsea.com/l2p2
25. https://www.gov.uk/guidance/apply-for-mentoring-in-nuclear-decommissioning-industry
26. https://www.compositesworld.com/columns/shared-databases-will-expand-composites-use-in-aerospace-and-beyond
27. http://www.jeccomposites.com/knowledge/international-composites-news/shared-databases-composite-materials
28. https://www.wichita.edu/research/NIAR/Research/ncamp.php

The centre would work closely with regulators, end-users and the supply chain to investigate commonalities for dataset requirements and operating conditions between product developments. It would then develop specifications and qualify materials in sectors beyond Aerospace, where there is currently little effort around these activities. It should seek to include simulation and virtual testing aspects to build-in development/validation/acceptance of quality assured characteristic data generated by validated analysis. The initiative would engage regulators to develop relevant specifications and subsequently qualify the materials against the agreed requirements.

The centre would also take on responsibility for the qualification of composite materials following the developed specifications, thus taking away this effort from the manufacturer so they can focus on design, process development and validation activities. The centre would orchestrate the creation, continuous update and maintenance of a database that will include validated data from physical as well as virtual tests able to provide the characteristic values for design. It would also curate and organise, while providing assurance to existing datasets for common use across industry sectors. Finally, it should bridge the gap between regulators, including regulatory documentation, in each sector with the manufacturers and the material suppliers closing the loop of stakeholders for a material qualification programme.

The centre would complement the services of commercial test-houses to the industry sectors on qualifying materials. Along a product's validation chain the centre would primarily cover the activities that are not design specific and hence non-proprietary data can be produced and consequently shared. It is therefore the main aim to produce shared data where commonalities have been identified.

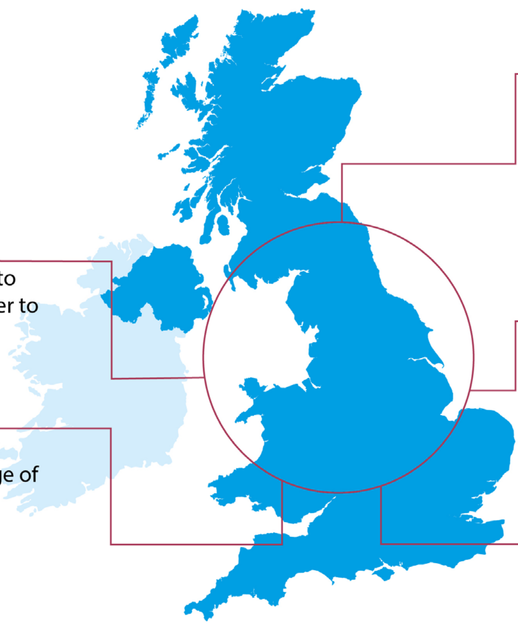
Distributed approach to materials assurance

One governance – many operational centres

Centralised governance but operations via a number of established centres close to industry

Better channelling of customers

The network makes it possible to serve industrial customers closer to their location



Centres that complement each other

The distributed network makes it possible to allocate tasks and focus resources instead of unnecessarily duplicated structures

Use of expertise

The distributed model makes it easier to access depth and range of expert knowledge

Network of training

Offer mentoring and training via the network of centres

The longevity of the initiative would need to be ensured. Following initial inward investment for establishing the centre this should be self-sustained by drawing revenue from the material qualification programmes and the mentoring provided to interested companies. To ensure uptake by industry, a cost sharing model needs to be considered making the cost for the individual companies affordable. The potential of offering paid mentoring (knowledge-based consultancy) on the certification process for companies that would accelerate their development would also need to be thoroughly investigated.

The initial capital investment required could be reduced by considering **a distributed model that would bring together existing centres of knowledge and technical capabilities** under a common governance model. A distributed model can be followed with centralised governance and resource planning while allowing to serve interested customers closer to their location.

To guarantee success of the centre it is essential that it has some authority from the relevant regulators in qualifying materials for the use in structural, safety critical applications in the sectors, allowing the regulatory authorities and classification societies to focus on certifying the final product.

To ensure ease of access the centre should be closely linked to existing entities in the UK composites landscape. In addition, working with regulators will provide enhanced visibility and accessibility. Experiences from the set-up and operations of the National Centre for Advanced Materials Performance (NCAMP) (see Appendix 2) could be used as a starting point for defining the scope, governance and operations of the centre. In addition to the governance and operational model, to create a common set of data, an agreed framework would need to be used. This could be provided by ISO 20144 (see Appendix 3).

5 Appendix 1: Industrial responses

1. Personal data

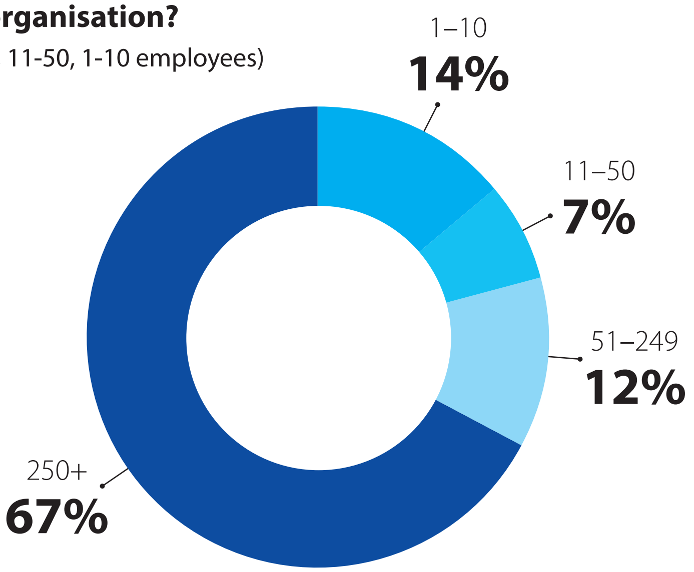
(name, email, organisation)

44 responses

2. How large is your organisation?

(over 250, 51-249, 11-50, 1-10 employees)

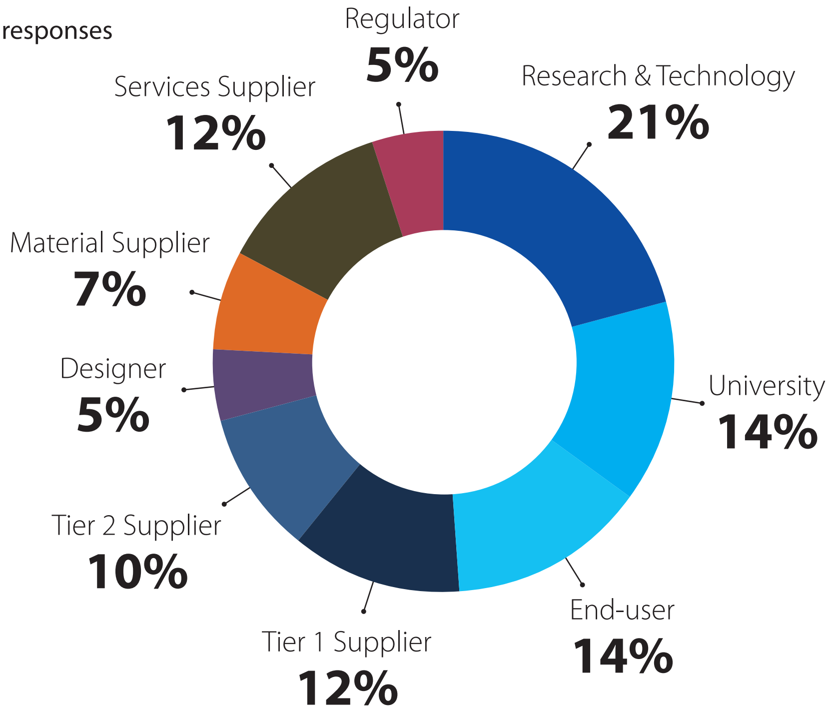
43 responses



3. What is the main activity of your organisation?

(End-User, Tier 1 Supplier, Tier 2 Supplier, Designer, Material Supplier, Services Supplier, Regulator, Research & Technology, University)

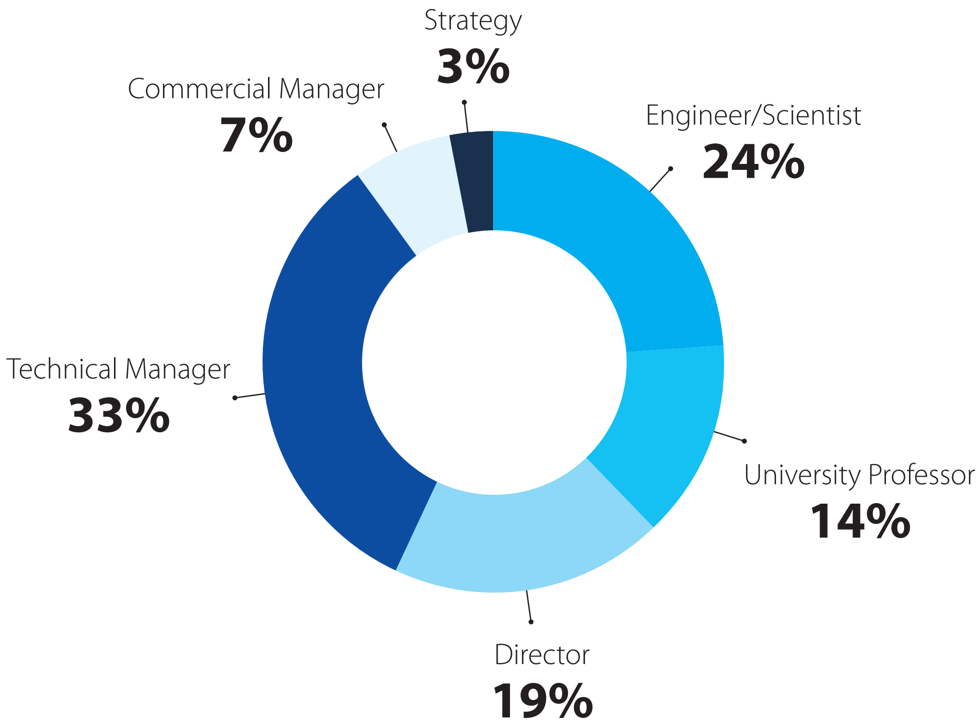
42 responses



4. What is your role in the organisation?

(Director, Technical Manager, Commercial Manager, Strategy, Engineer / Scientist, University Professor)

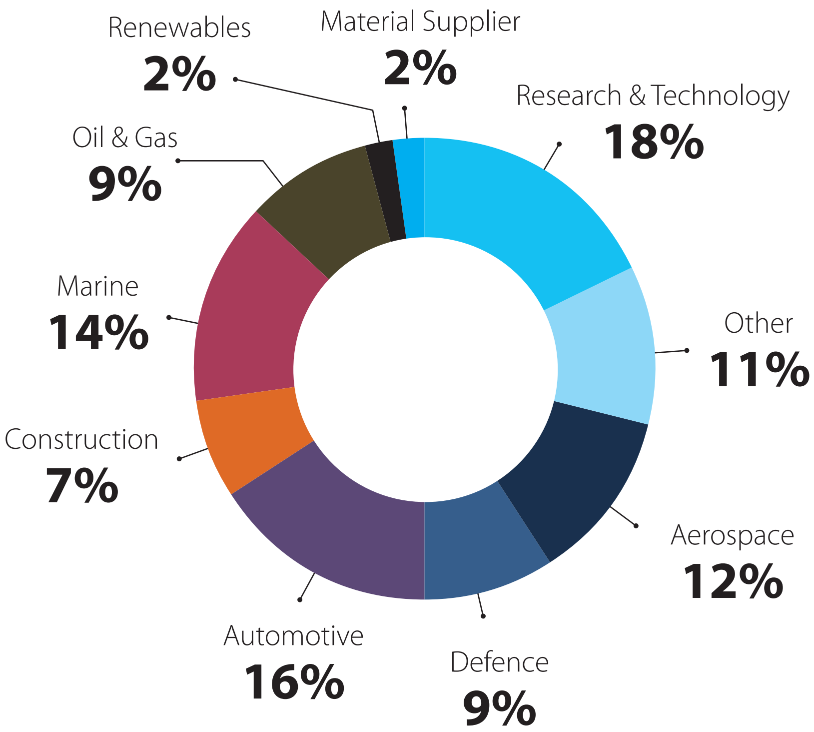
42 responses



5. Which is the main industrial sector your organisation operates in?

(Aerospace, Defence, Automotive, Rail, Construction, Marine, Oil & Gas, Renewables, Material Supplier, Research & Technology, Government, Other)

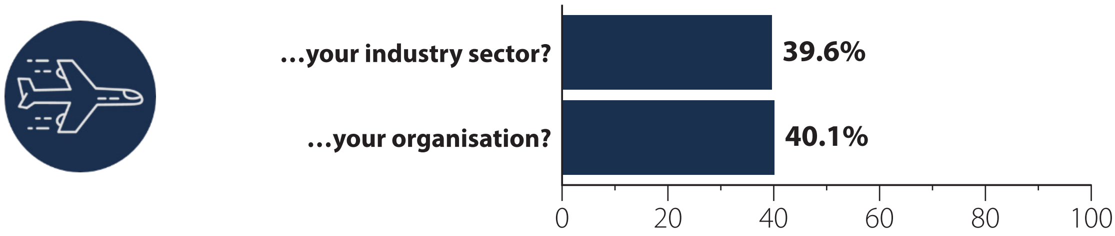
44 responses

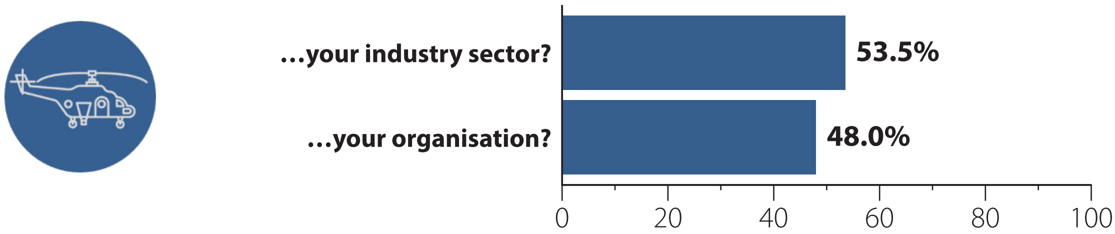


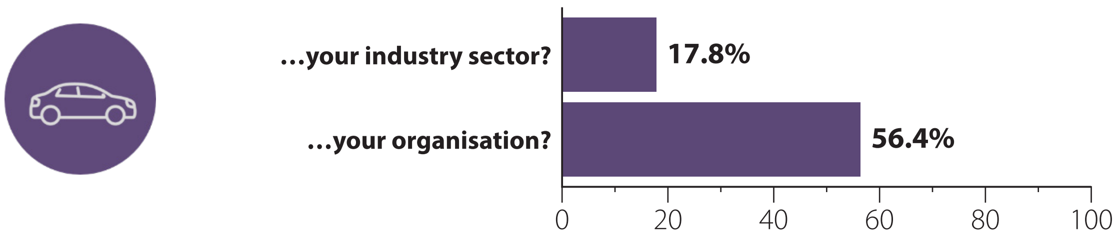
6. In your opinion, what is the current use of composites in…

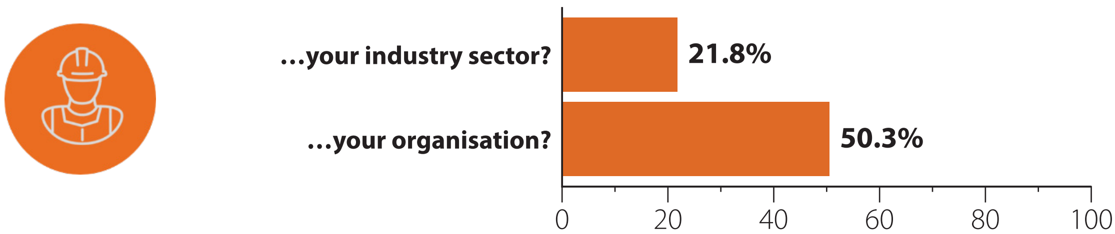
(provide % up to 100%)

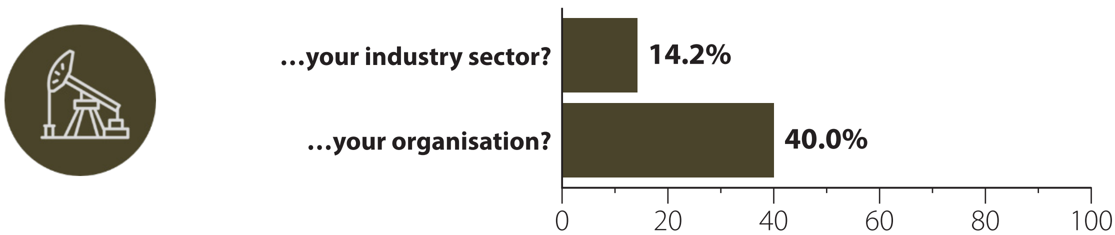
35 responses

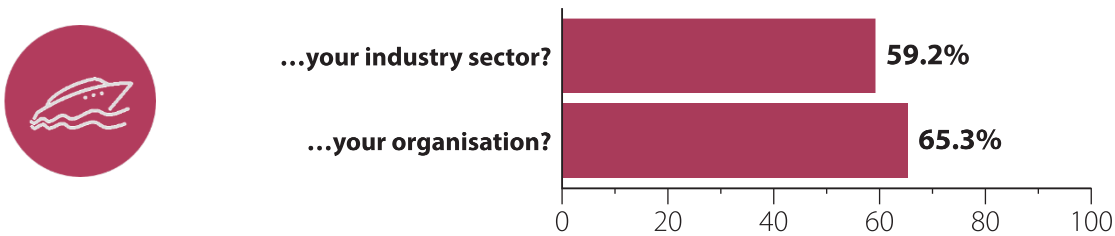








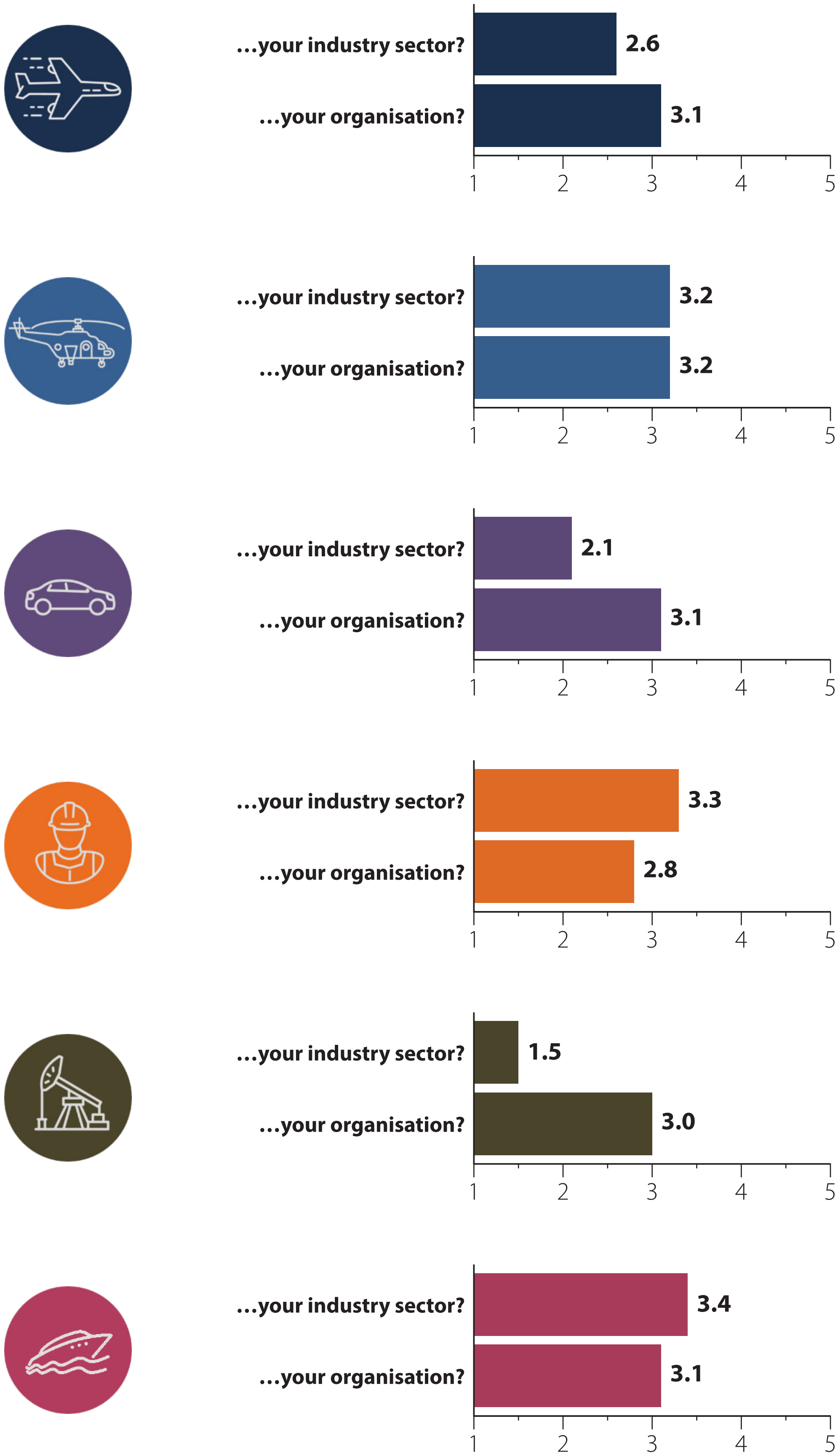




7. How familiar is the average engineer with composite materials in…

(rate from 1(slightly) to 5 (very))

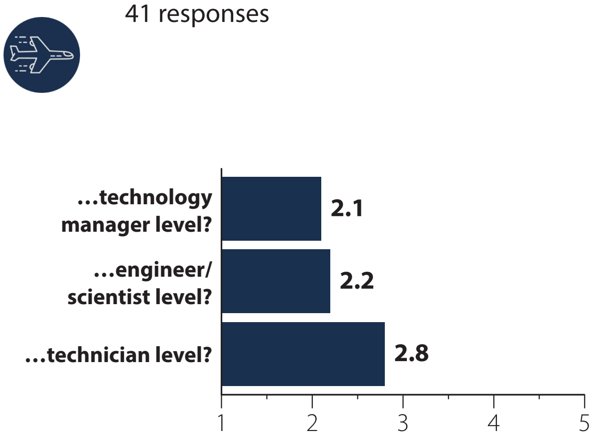
39 responses

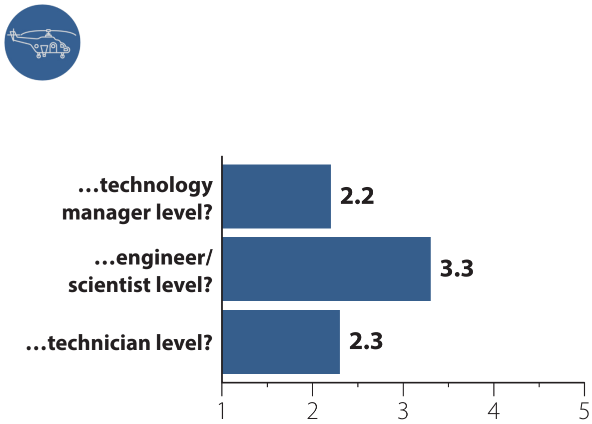


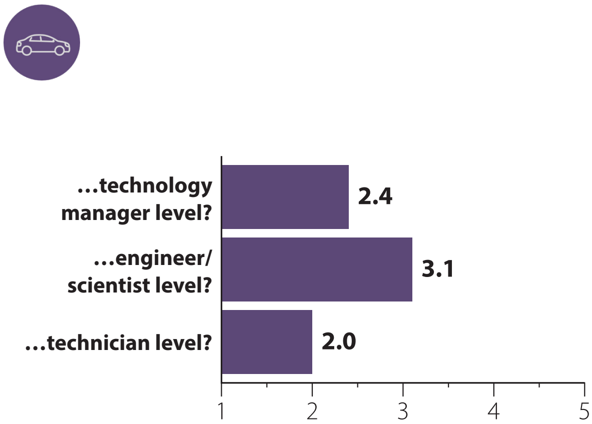
8. How sufficient is the available composites related training at…

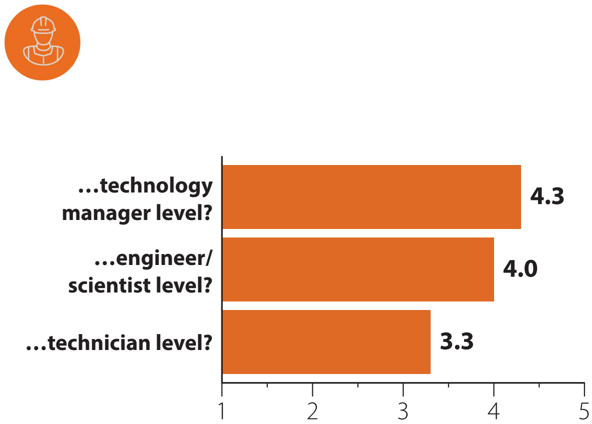
(rate from 1(slightly) to 5 (very))

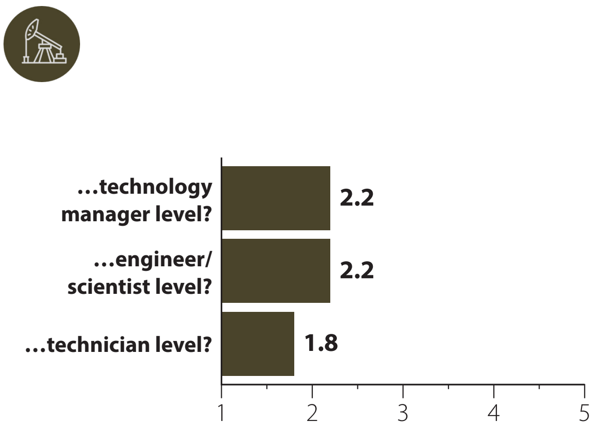
41 responses

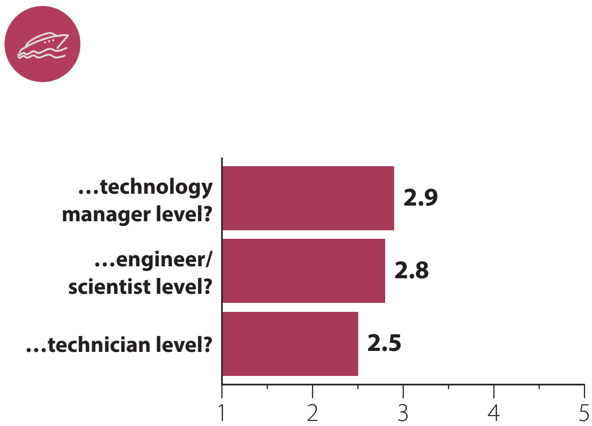








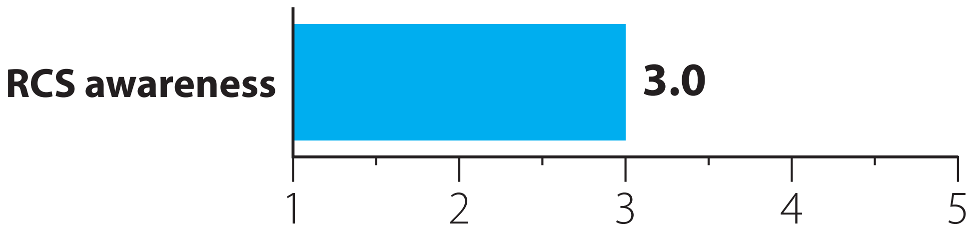




9. What is the level of RCS awareness in your organisation?

(rate from 1 (low) to 5 (high))

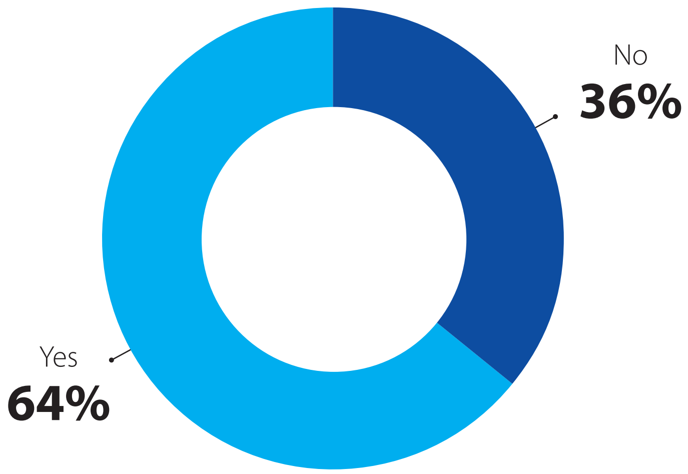
41 responses



10. Is your organisation involved in developing or revising regulations, codes and/or standards?

(yes, no)

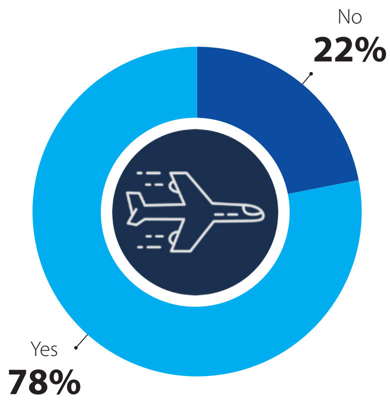
42 responses

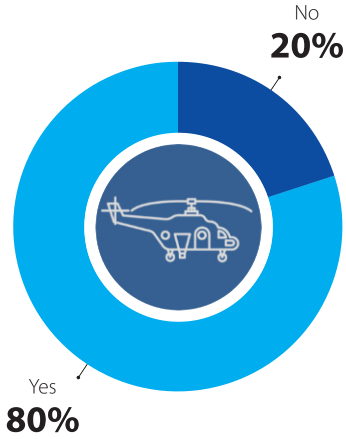


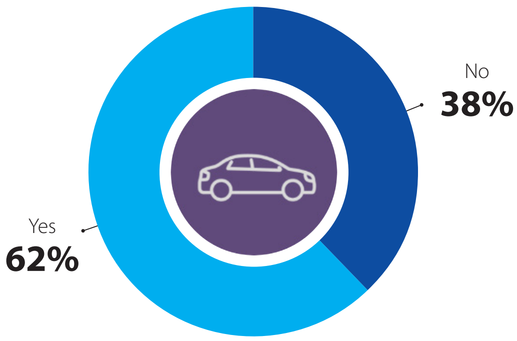
A1. Do you employ a building block type approach for evaluating the performance and qualifying a product?

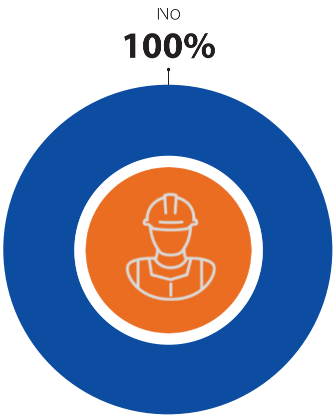
(yes, no)

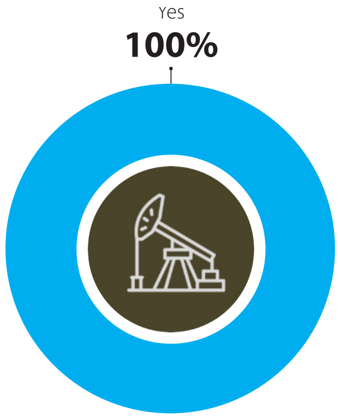
39 responses

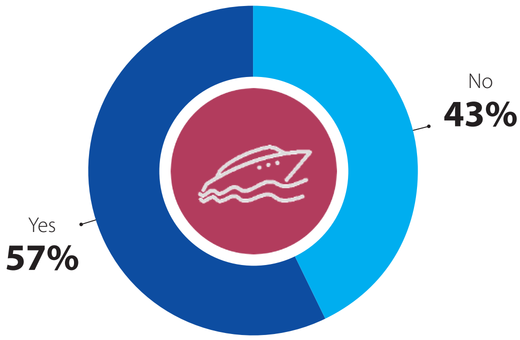












A2. If No, how are composites products qualified for use in your industry sector?

1. Numerous methods applied across different ATA needs
2. The sector has a building block. In my company we do qualify but the building block is more flat
3. Internal procedure based on FAA/EASA accepted guidance as found in CMH-17

1. Analysis and test
2. Process control and review post manufacture

1. Individual tests from coupons through to components
2. Ad-hoc
3. Qualification is poorly understood and based on crash performance. OEMs take the risk for other performance criteria
4. Homologation in auto sector
5. We crash the vehicles
6. Little applicability for middle of the qualification triangle

1. Individual project based assessments by the Head of Profession
2. On a case by case basis using different mechanisms/systems in different industries
3. Our materials are tested to the related standard applied to the application. This demonstrates we meet or exceed the standard
4. Based on standard tests performed on the materials
5. In rail, we challenge a standard to have composites included as a material and attempt to change the standard or test method

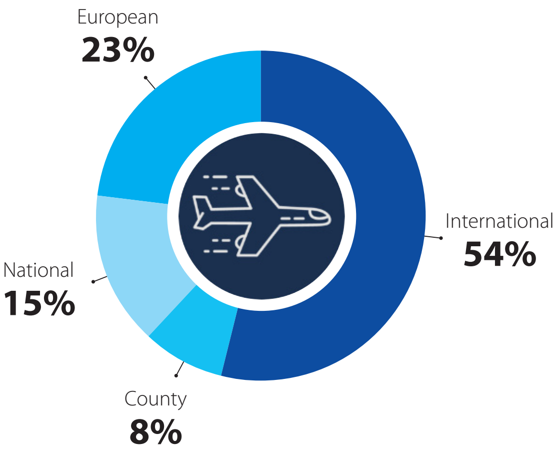
1. Engineered repairs - type approval through Lloyd's/ DNV/ABS or second company qualification
2. Using the BB approach for marine and O&G
3. Composites are qualified in the industry sector by gaining approval to National (BS) and International Standards (e.g. EN/ISO) which are linked to relevant Regulations (ADR/RID)

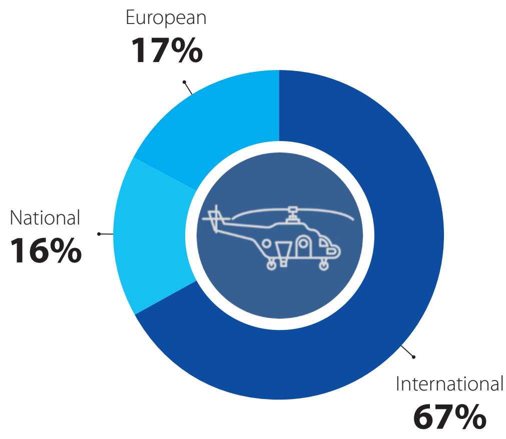
1. Depends on the vessel. Small dinghies are very different to SOLAS Reg vessels where block system is applied, more or less
2. I would say that we use the concept of the building blocks but in the marine sector it is perhaps less obviously structured than aerospace.
3. In Marine it is done for individual products in individual companies but there is not a recognise way of sharing qualified materials to move up the certification pyramid.
4. Standard products are Wheel marked, typically. IMO Standards are international.
5. We validate the material properties stated on the data sheets to test in our facility using our equipment and processes
6. There is often large variability in the material properties that can be achieved even with the 'raw' materials e.g. structural foams

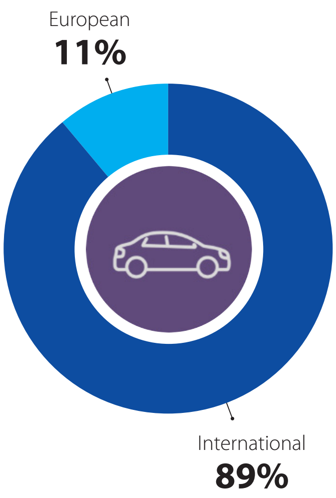
A3. How geographically spread is the product qualification process in your industry sector?

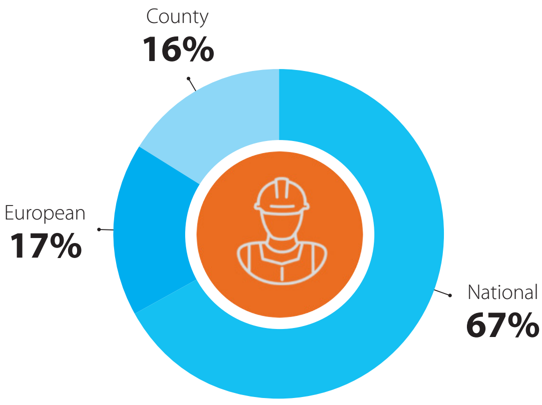
(County, National, European, International)

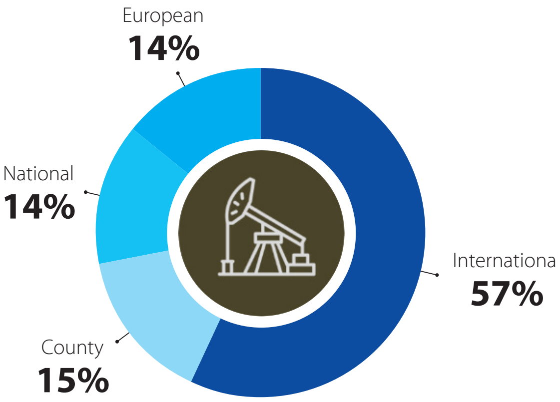
41 responses

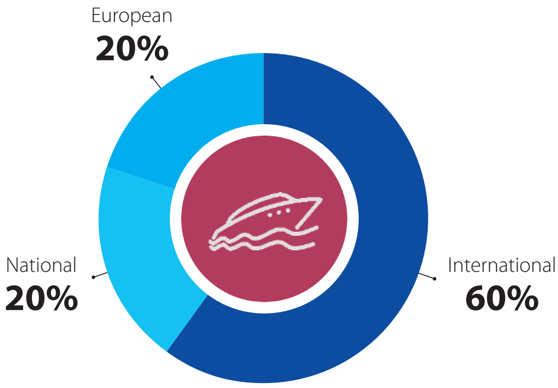








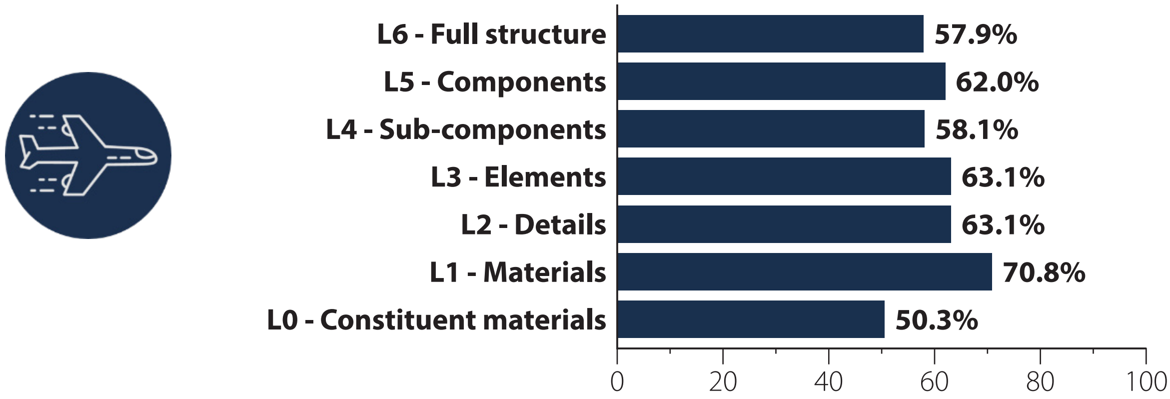


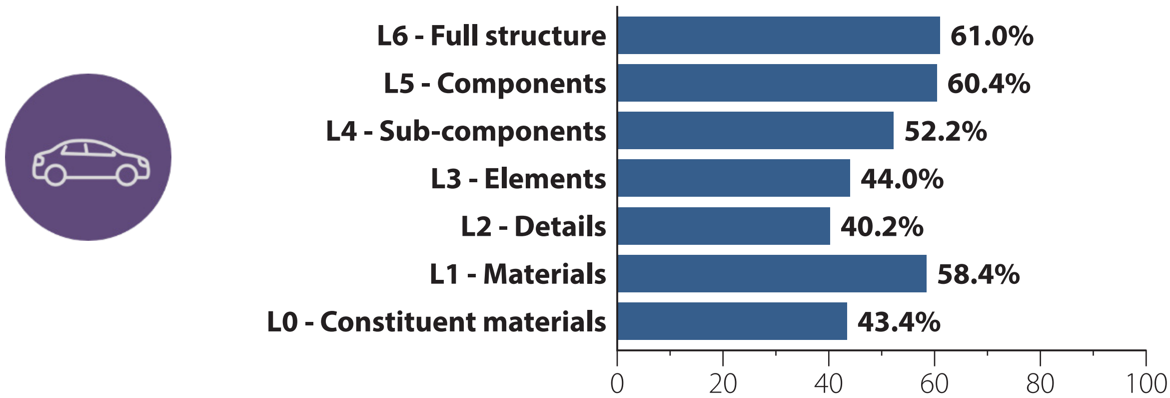


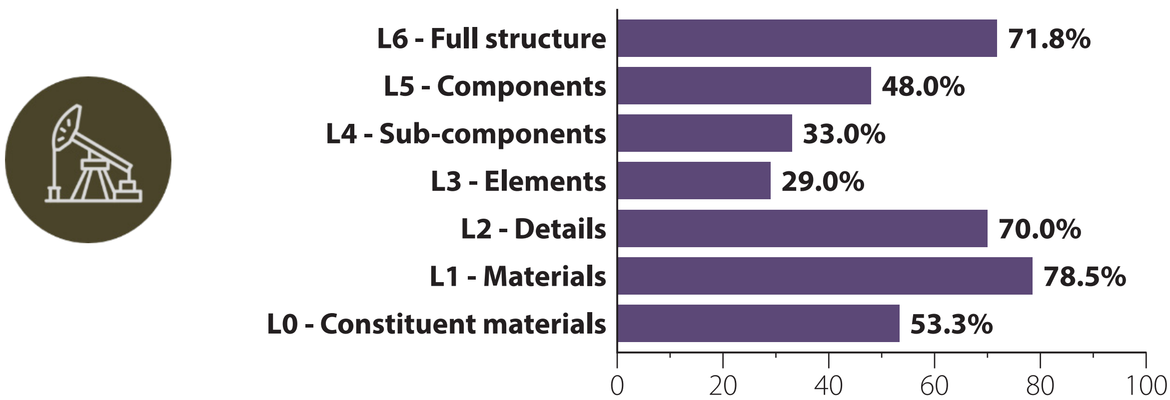
A4. At what % do you perform physical and virtual tests at each level of the building block approach in the product approval process?

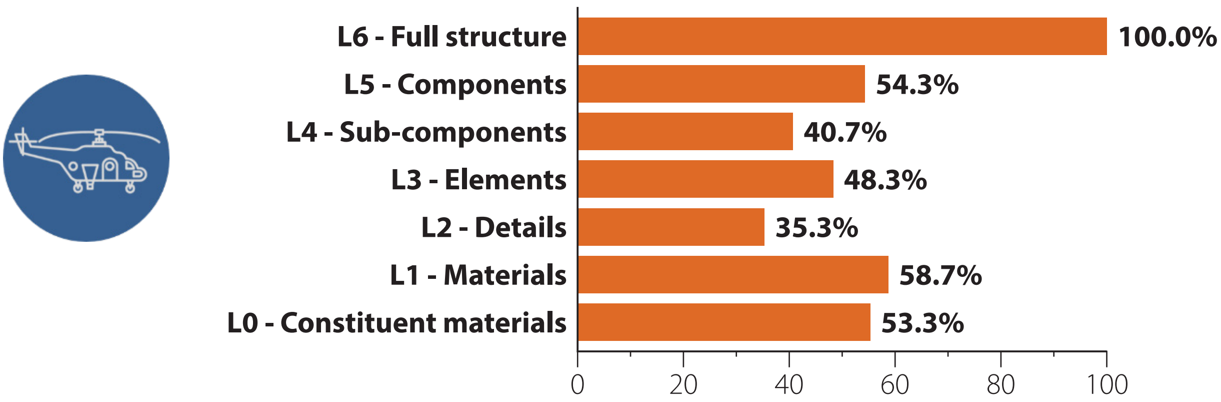
(from 0 (only virtual) to 100 (only physical))

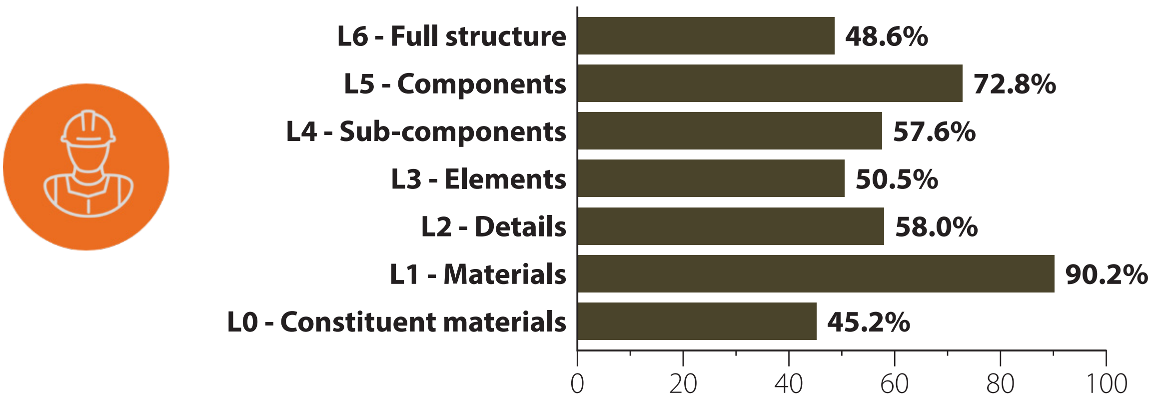
35 responses

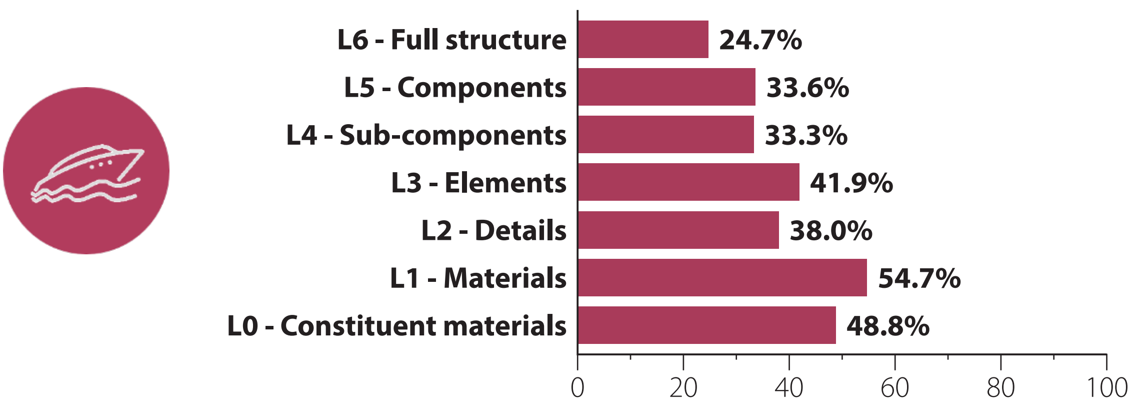







L6 - Full structure 100.0%
L5 - Components 54.3%
L4 - Sub-components 40.7%
L3 - Elements 48.3%
L2 - Details 35.3%
L1 - Materials 58.7%
L0 - Constituent materials 53.3%
0 20 40 60 80 100

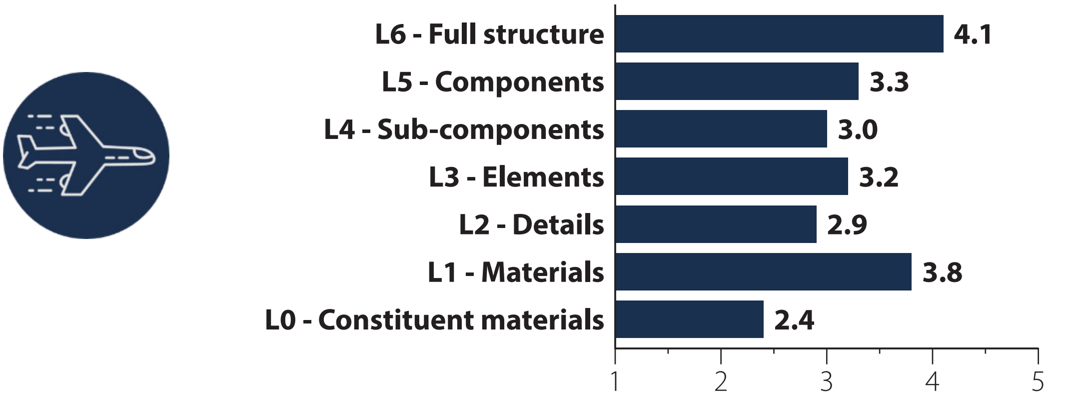

L6 - Full structure 48.6%
L5 - Components 72.8%
L4 - Sub-components 57.6%
L3 - Elements 50.5%
L2 - Details 58.0%
L1 - Materials 90.2%
L0 - Constituent materials 45.2%
0 20 40 60 80 100

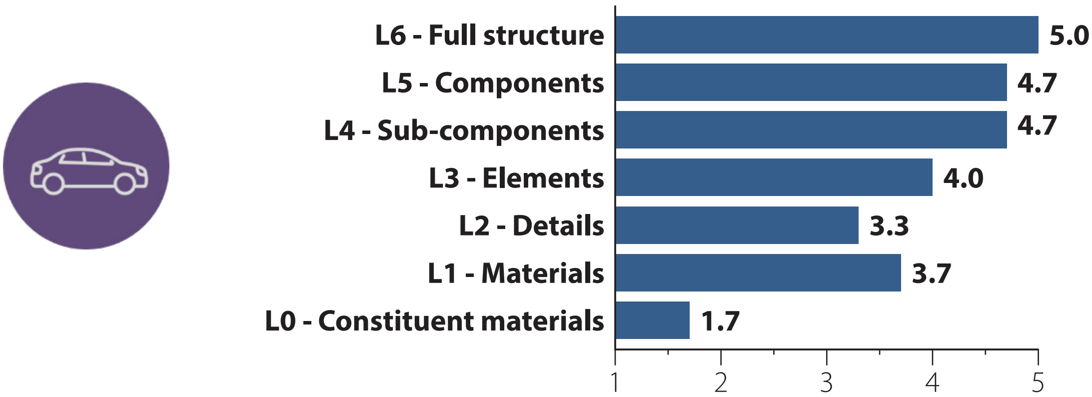

L6 - Full structure 24.7%
L5 - Components 33.6%
L4 - Sub-components 33.3%
L3 - Elements 41.9%
L2 - Details 38.0%
L1 - Materials 54.7%
L0 - Constituent materials 48.8%
0 20 40 60 80 100

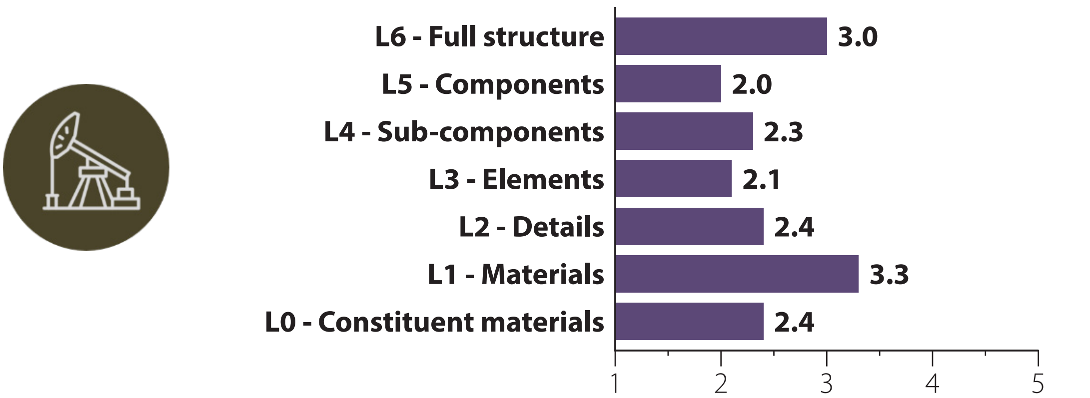
A5a. In your experience, which levels of the building block approach are the most time consuming?

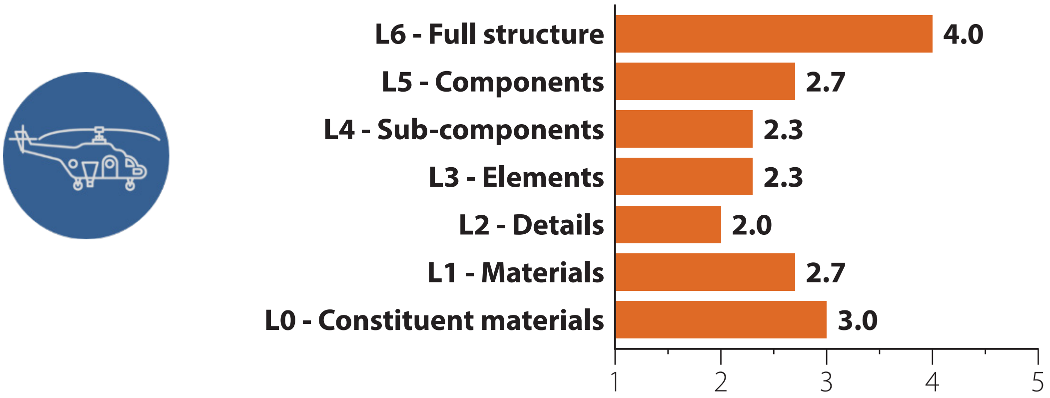
(rate from 1 (least) to 5 (most))

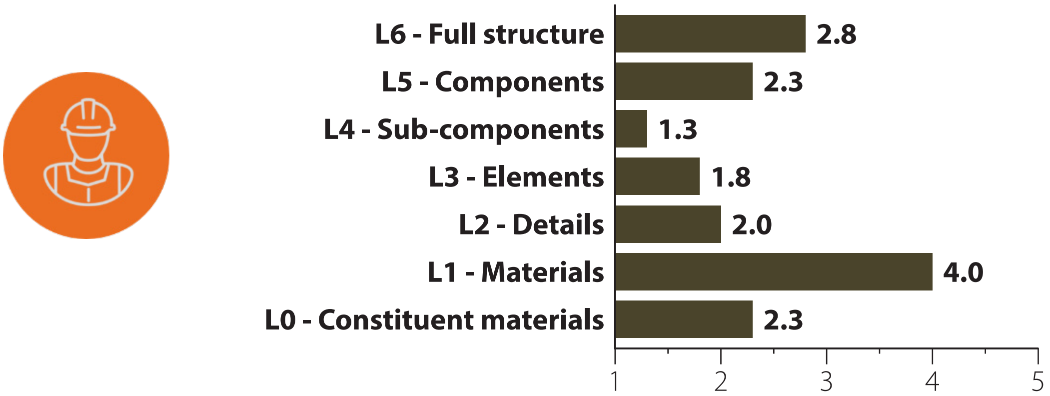
33 responses

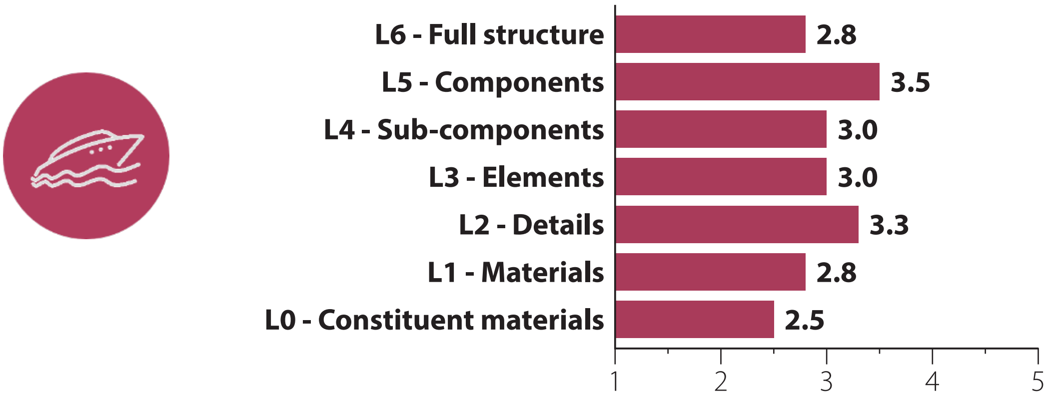







L6 - Full structure 4.0
L5 - Components 2.7
L4 - Sub-components 2.3
L3 - Elements 2.3
L2 - Details 2.0
L1 - Materials 2.7
L0 - Constituent materials 3.0
1
2
3
4
5


L6 - Full structure 2.8
L5 - Components 2.3
L4 - Sub-components 1.3
L3 - Elements 1.8
L2 - Details 2.0
L1 - Materials 4.0
L0 - Constituent materials 2.3
1
2
3
4
5


L6 - Full structure 2.8
L5 - Components 3.5
L4 - Sub-components 3.0
L3 - Elements 3.0
L2 - Details 3.3
L1 - Materials 2.8
L0 - Constituent materials 2.5
1
2
3
4
5

A5b. What can be done to reduce the overall time for the benefit of your organisation and industry sector?

1. CFRP to be standardized as it happens with metals and alloys
2. Topics discussed here database, virtual testing and simulation
3. Optimise the environmental conditioning of the test pyramid
4. Progress a Digital twin that has qualified uncertainty to mitigate variability in tests
5. Reduce physical testing & develop and validate virtual testing processes
6. Standardising testing for certain types of features
7. More shared data/resources, reduced need for coupon tests where data can be obtained by virtual tests or higher-level tests
8. Standardisation of the material formulations
9. Less physical testing - develop/validate virtual test processes
10. Less physical testing - develop/validate virtual test
11. Less physical testing - more virtual testing

1. Shrink the middle of the pyramid and validate virtual qualification
2. New approach and virtual testing
3. Education
4. Test properties that relate only to failure mode and virtual testing

1. Agreed standards for different materials, formats and structures with data that substantiates these choices. Include joining and multi-materials
2. Standards for coupon tests are not relevant for composites emerging into market (braided) which behave differently
3. Baseline CAE datacard for generic intermediates matched to main processes
4. Simple solution for non-aware decision makers
5. Modelling tools and appropriate materials data
6. We need a broad acceptance of standard tests for mechanical properties and realistic lower bound values of them for composite materials suppliers to supply standard materials to a specification
7. Need groupings of material behaviour to classify different materials based on relevant shapes
8. Need cheap and relevant feature based test standards (i.e. how does x composite behave in a tube)

1. A national database of composites that lists specific properties
2. Sharing of data. Use of generic properties
3. Clear test data of similar testing easily accessible

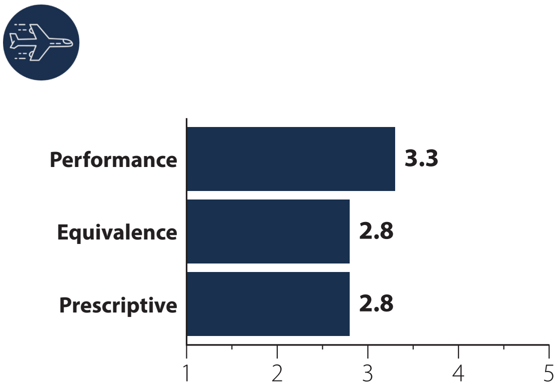
1. End user understanding of composite materials, matching the qualification effort with the risk profile of a given application
2. Predictive or correlation tools regarding environmental effects and strength degradation. May or may not be possible though!
3. More detailed end product specifications of acceptable performance
4. Introduce virtual testing and on-line NDE
5. Technology to assess long term performance

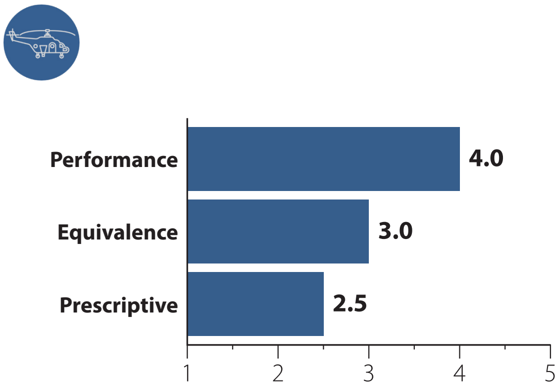
1. Simplified tables
2. Performance related standards approach
3. Standardised materials for appropriate applications
4. Have RCS that are specific for composites. Drop guidelines that ask for equivalence to steel
5. Overall having more consistency across all levels of the building blocks would help. Increased visibility of all stakeholders for each level would be useful as this could then be used to try and bring them together for the 'greater good' as it were
6. If one could find a way of sharing qualified materials it would reduce the time and cost of certification of the products. This would have to be achieved through confidence of manufacturer of liability issues and the confidence of the regulator
7. Share test data across sectors/industry
8. Using more informative experiments at the higher levels of the pyramid that are more representative of the composite structure and integrate with modelling i.e. virtual testing
9. Ensure tests are consistent between test houses. Reduce test house lead times. Currently not commercially viable in the marine industry
10. For example, having access to material test data and/or having a standard template for material technical data sheets would be good as well as having a single standard for the actual tests that the data derives from

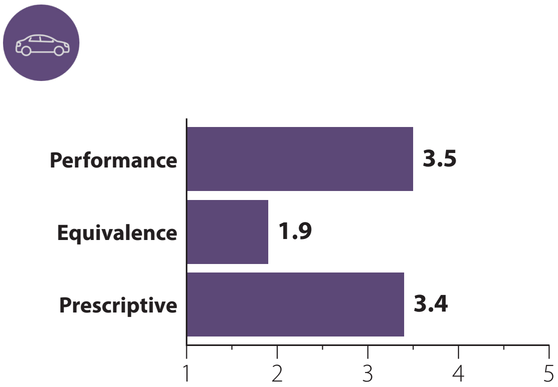
A6a. How would you characterise the regulations in your industry sector?

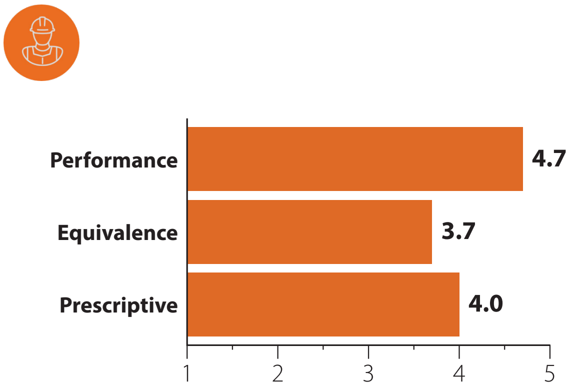
(rate from 1 (strongly disagree) to 5 (strongly agree))

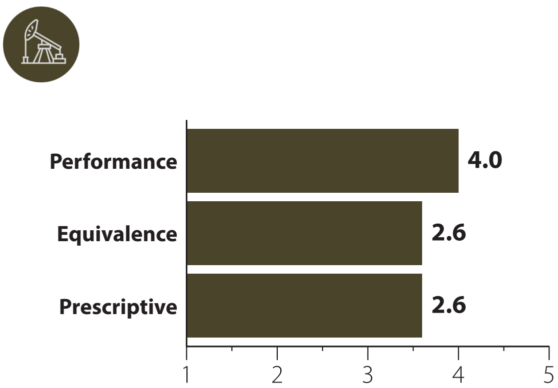
35 responses

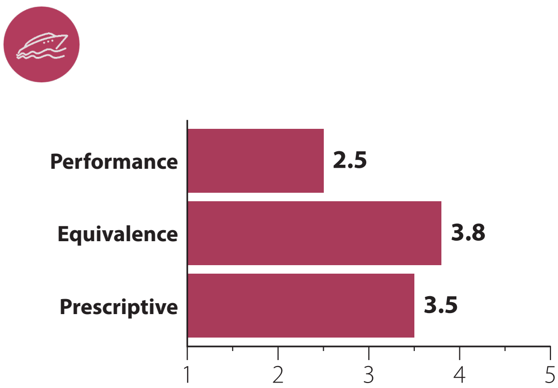








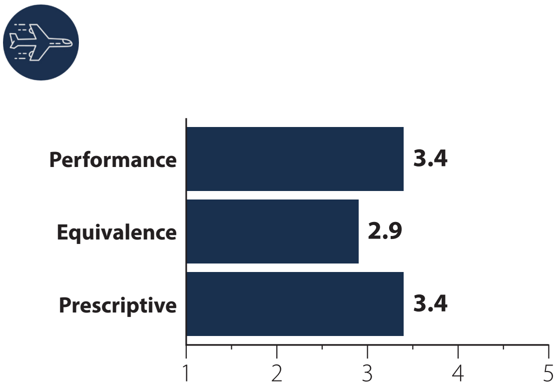


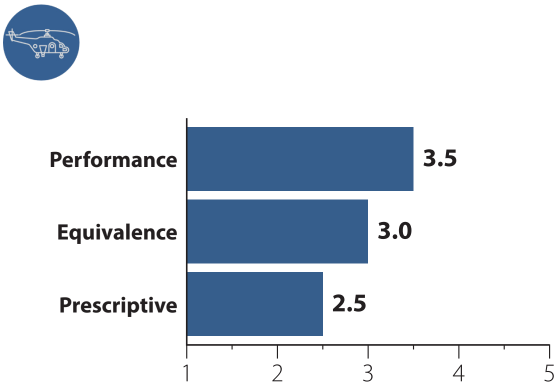


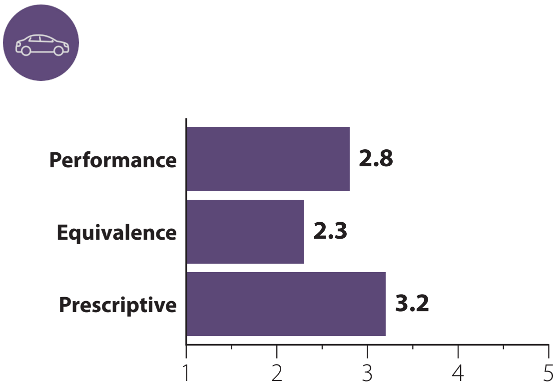
A6b. How would you characterise the codes in your industry sector?

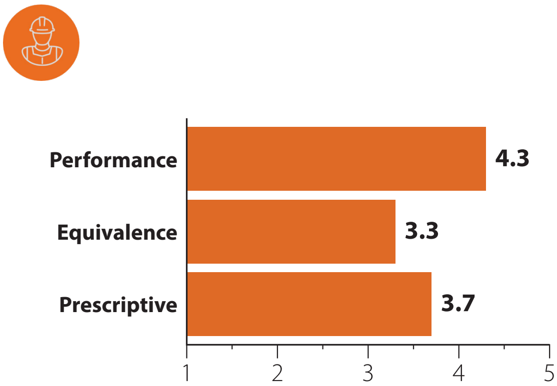
(rate from 1 (strongly disagree) to 5 (strongly agree))

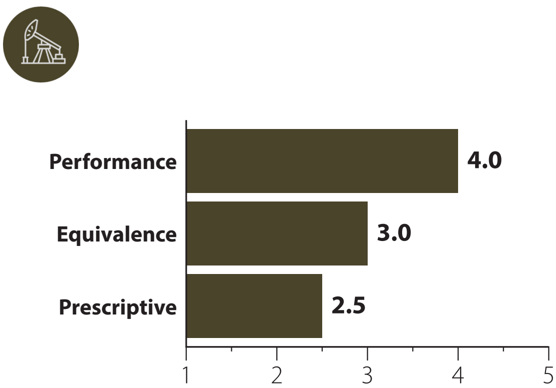
35 responses

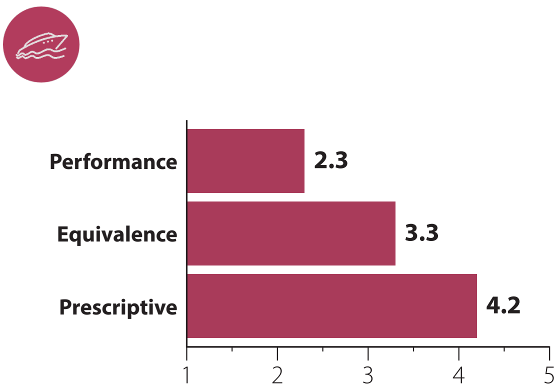








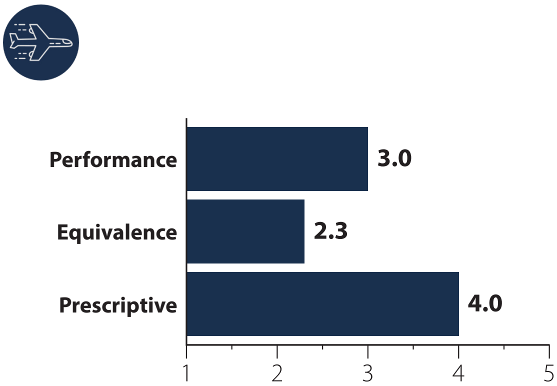


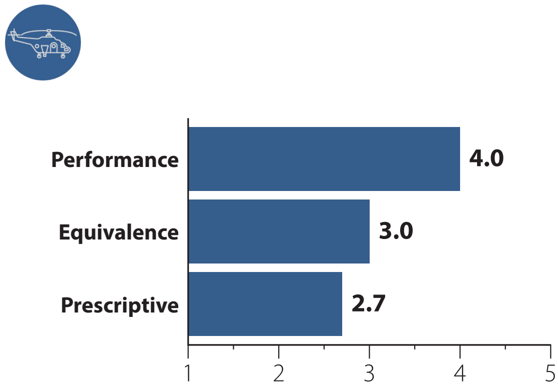


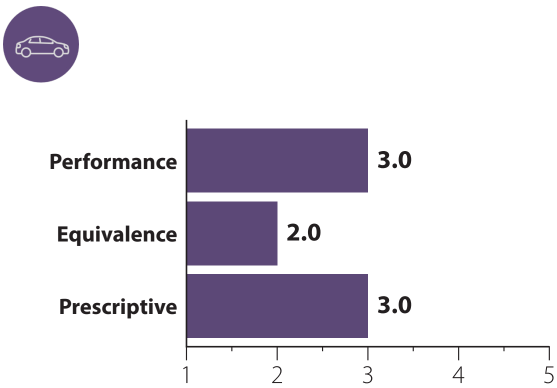
A6c. How would you characterise the standards in your industry sector?

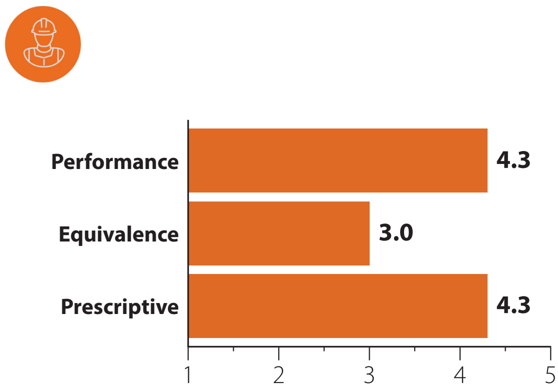
(rate from 1 (strongly disagree) to 5 (strongly agree))

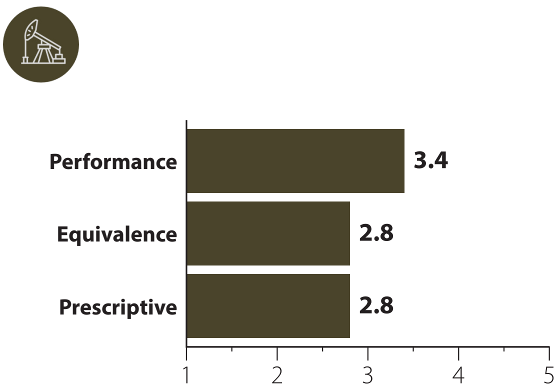
35 responses

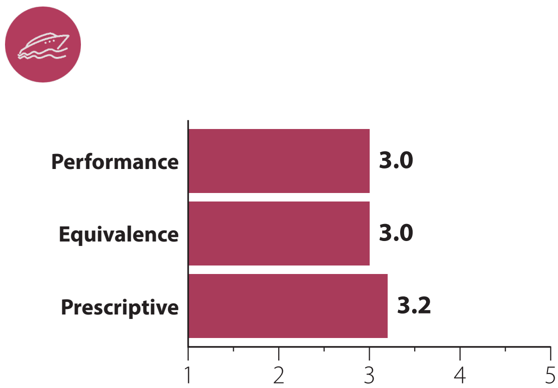








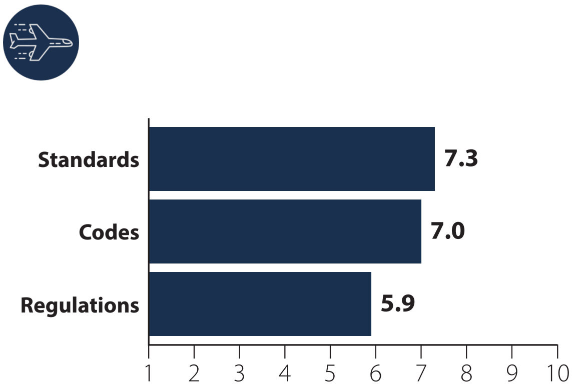


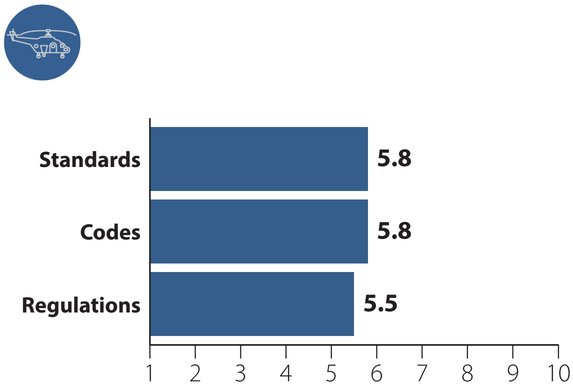


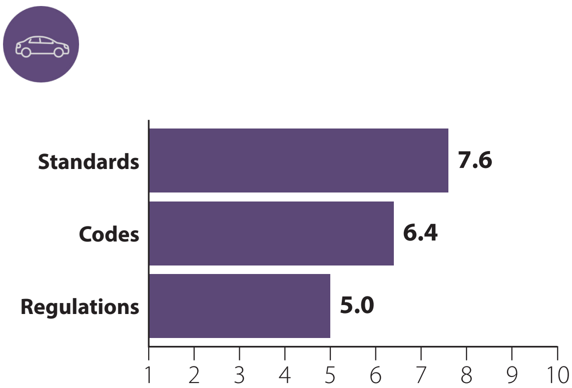
A7. Which one of the RCS, and by how much, needs to change in your industry sector to maximise the use of composites?

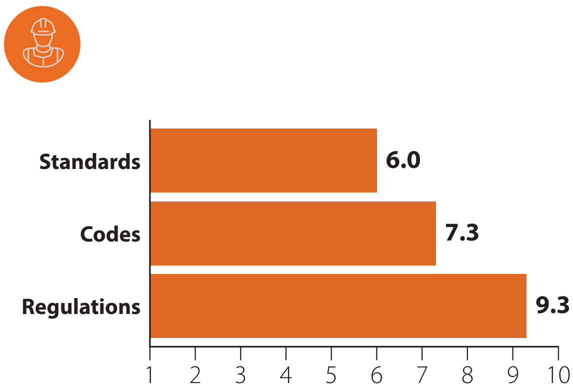
(rate from 0 (no change) to 10 (outright change))

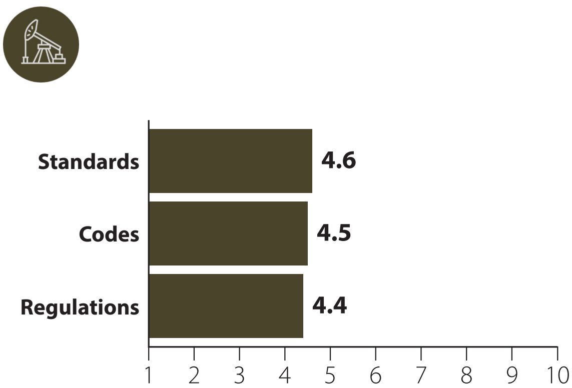
35 responses

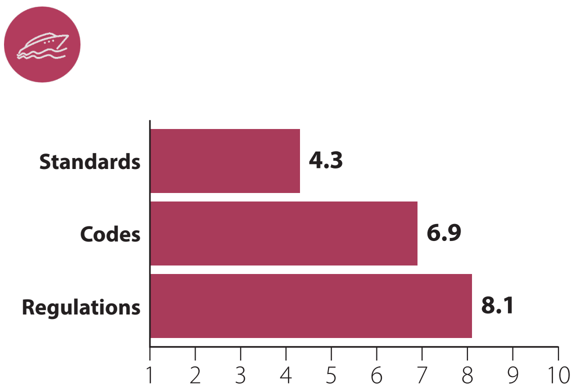








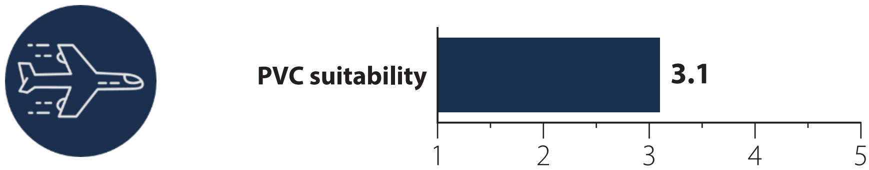


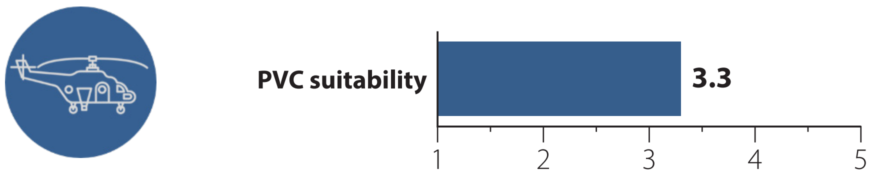


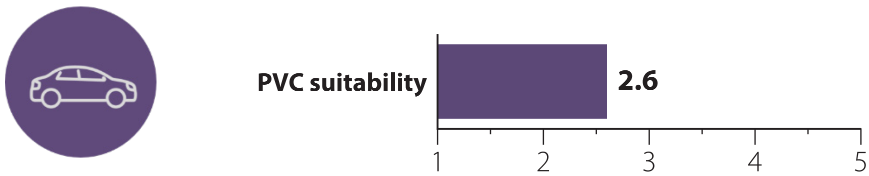
B1. Do you believe that the PVC sufficiently describes the route to product approval for your industry sector?

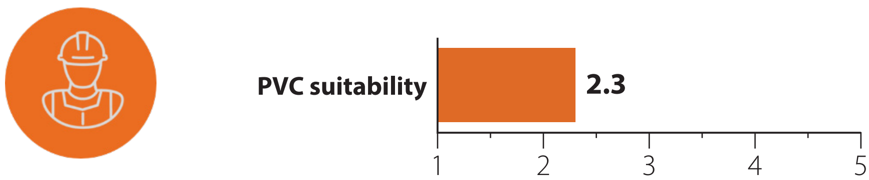
(rate from 1 (strongly disagree) to 5 (strongly agree))

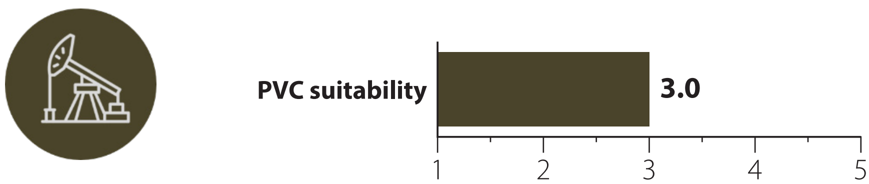
36 responses

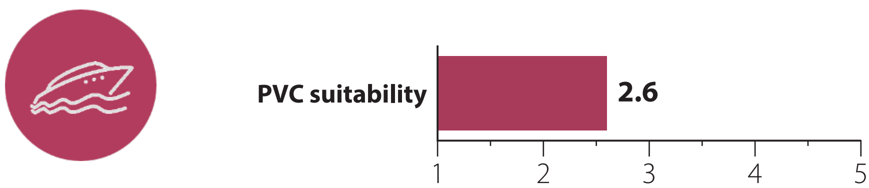












B2. How can the PVC be improved to better suit the needs of your industry sector?

1. Standardized material specification identical to metals
2. Virtual test confidence levels and validation
3. Need to consider Top Level Industrial Requirements, not just Top-Level Aircraft requirements, driving a change in the V&V model
4. It should include variation in manufacturing methods and the impact it has on the fibre and/or matrix
5. Less complex

1. Create standards for virtual assurance
2. It needs bringing into the virtual world
3. Need to consider how we address the prediction of performance in a fire environment
4. The current pyramid is applicable to structural integrity and not to other load environments. There is no coherent approach across sectors linking fire response in the lab to the fire response of the in-service system

1. 'V' model linking material capability with standards
2. The PVC needs to be built up every time from scratch. Need more data at the bottom
3. Guidance notes, training
4. Simplicity is key
5. Not appropriate for Automotive short development cycles. Need more modelling tools and standardised materials properties
6. Recognise that the aero pyramid does not apply for auto where the certification at the top is totally different from the properties measured at the bottom
7. End of life and recycling needs included
8. Consider a systems engineering style V model for assurance and making relevant standards or regulations at the necessary stage
9. Regulations are driving the interest in composites but its not direct. They focus on reduced emissions and crash none of which are measured until the end of the process

1. Needs to include regulators to give assurance that qualification/approval will be given at end of process. Guidance from SQEP during this approval process is crucial
2. Include regulators/stakeholders at right point to avoid delays
3. Use of generic specifications

1. It depends on the service of the product. For regularly repeatable tasks - possibly but much of our requirements are bespoke
2. It needs to be implemented recognising that as it is new in the O&G all parties involved must invest in the process
3. Include long term environmental performance
4. Published R&D regarding environmental effects at element / design detail level. Would help to reduce the almost endless permutations of mid-level testing
5. To address life in applications that are environmentally driven as well as load driven. To better identify when in the PVC a product is "qualified"
6. Globalisation e.g. acceptance of resins varies geographically
7. Keep it simple! Standards that are overly prescriptive or not industry specific could limit deployment

1. Needs to include design
2. Needs to include end of-use/life
3. There is a lack of info available covering the process. Cure cycle data comes from material supplier but is nearly always adjusted by the manufacturer. Final product testing may be product specific. Fibre and material specs are well covered
4. Re-format the PVC as a clear process; Could also include through life monitoring procedures; suggest including design procedures and also disposal / end of life / end of use procedures and lifecycle assessment (e.g. marineshift 360)
5. The PVC route is poorly defined for Marine. Greater definition would help
6. Marine certify products in stovepipes without sharing
7. Share access to qualified materials would simplify/shorten and reduce the testing costs
8. There needs to be a flexible procedure based on performance that allows SMEs to engage in designing composite structures
9. The way data is presented needs to be standardised. Subcomponent test data and standards, adhesives, bolts, is improving but data tends to be manufacturer sourced. Could be standardised
10. Need standard or code for virtual simulation of composites e.g. FEA. In addition, would be good to have a standard accreditation for FEA composites analysts e.g. through NAFEMS? Furthermore, the FEA software itself-should there be regulation of this?
11. It would also reduce costs and allow small material manufacturers to work with multiple OEMs to reduce costs
12. Also, the regulator could have more confidence is qualified materials
13. Make marine better defined and shorten it for non-SOLAS and SOLAS
14. Develop common acceptable materials
15. Embed regulators in process
16. Train more SQEP people for regulators

B3. For each one of the levels of the PVC, assess the degree to which formal, agreed specifications, procedures, standards, test methods exist and are publically available in your industry sector – Availability?

(rate from 1 (low) to 5 (high))

33 responses

1. Fibre and Matrix Test Methods	3.3	4.0	2.8	3.5	4.0	3.1
2. Fibre and Matrix Specifications	2.3	4.0	2.6	3.0	3.2	3.0
3. Materials and Process Test Methods	3.7	3.3	2.3	3.3	3.5	2.6
4. Format and Moulding Specifications	2.3	2.5	1.8	3.0	2.5	2.7
5. Laminate Test Methods	3.7	4.0	3.3	3.5	2.8	3.4
6. Composite Specifications	2.9	3.0	2.3	3.7	2.8	2.7
7. Structural Details Test Methods	2.1	2.3	2.3	3.7	2.0	1.7
8. Sub-component Approval Procedures	2.1	1.5	1.7	3.0	2.4	1.3
9. Full Scale Test Methods	2.1	1.5	2.3	3.3	3.0	2.3
10. Final Product Approval Procedures	2.6	2.5	3.3	3.3	2.7	3.0
11. NDE Test Methods	2.6	2.5	1.4	2.7	1.8	2.1
12. Repair & Maintenance Procedures	2.1	2.3	1.7	2.7	1.7	2.5

B4. For each one of the levels of the PVC, assess the degree to which your organisation can and does use these procedures – Implementability?

(rate from 1 (low) to 5 (high))

31 responses

1. Fibre and Matrix Test Methods	2.9	3.3	2.1	2.5	3.3	2.7
2. Fibre and Matrix Specifications	2.9	3.3	2.7	2.0	2.8	3.0
3. Materials and Process Test Methods	3.1	2.8	2.4	1.5	2.7	2.5
4. Format and Moulding Specifications	2.1	2.3	2.0	1.5	2.3	2.3
5. Laminate Test Methods	2.9	4.0	2.7	2.5	3.3	3.2
6. Composite Specifications	2.3	3.8	2.4	2.0	3.0	2.8
7. Structural Details Test Methods	2.8	2.0	2.4	2.0	2.4	2.4
8. Sub-component Approval Procedures	2.3	2.0	2.4	1.5	2.0	2.4
9. Full Scale Test Methods	2.7	2.0	3.0	1.5	3.0	3.0
10. Final Product Approval Procedures	3.2	2.3	3.9	1.5	3.0	3.2
11. NDE Test Methods	2.7	3.0	1.7	1.5	2.0	2.4
12. Repair & Maintenance Procedures	2.0	2.0	1.9	1.5	2.0	2.6

B5. MATERIALS - What are the most important missing specifications, codes, standards and test methods for your industry sector?

1. Electrical and thermal conductivity
2. Nonstandard angles
3. Welded or bonded joints
4. High strain rate testing
5. The real issue is not the codes/standards per se, but the regulatory framework across sectors that defines the validation/certification processes
6. As we are driven by customer standards by a program level it's hard to determine what is missing as we may simply not realise how to get access to these, but they may exist
7. Tests representing higher up in the pyramid
8. Infusion process standards
9. Fracture mode 3 testing
10. Newer materials e.g. short fibre, thermoplastic
11. Edge protection standards
12. NDT for honeycomb structures
13. More material procurement norms
14. Nano and AM composite material standards
15. Through thickness strength testing improvement
16. Industrial requirement on 0.1mm polymer. Education norm need

1. Virtual testing
2. 3D Composites
3. Materials as in fibre - not that important
4. Methodology to relate laboratory-based fire properties to the system performance. E.g. TGA, DSC and cone calorimetry

1. Testing linked to component end use vs coupon testing that may not be representative
2. Raw data for fibre and matrix. The middle bit does not lead to the final vehicle certification which is crash and emissions
3. CAE datacard for auto sector
4. Damageability and 'group' identification
5. Material properties
6. Standards for virtual testing
7. Fire smoke and toxicity are clear for final product or raw material but missing in the middle of the pyramid

1. None specifically
2. There is a serious lack of standards in using new additives such as nano-particles such as carbon nanotubes, graphene, nano celulose, metal nanoparticles, etc.
3. NDE
4. Involvement of regulators with suitable SQEP in this process is severely lacking
5. Link between virtual and physical testing

1. Inspection of composites and life extension of defined life repairs is an issue
2. Laminate test methods at high strain levels where the material has become non-linear
3. NDE and structural integrity assessment
4. Laminate compression and reversed loading fatigue test standards
5. Laminate test methods for use for O&G type materials and geometries, i.e. not flat laminate, unidirectional based

1. Composite specific RCS from IMO for large SOLAS vessels
2. Standards relating to different processes
3. Ones for damage tolerance; natural fibres & bio resins; composites with embedded sensors, effects of ageing,
4. Qualification for regulators and classification personnel
5. Common agreed material qualifications
6. Mentors for qualification and certification
7. NDE of composite materials, allowable defects, kissing bonds
8. Damage tolerance - a technical understanding of the issues involved under service conditions for a variety of structures
9. Standards for damage tolerance
10. Standardisation & accreditation of NDT test methods & practitioners
11. Need to establish the reliability and approvability of virtual testing
12. A clear definition of what is understood by NDE/NDT for each industrial sector
13. Processing standards including disposables to use for different materials and design intent
14. Suitably qualifier structure engineers with material manufacturer
15. Closer interaction between modelling -i.e. the virtual world - and the testing environment - integration of testing and modelling higher up the pyramid
16. Standard approach to resolve obsolescence issues and changes in REACH legislation
17. Standard set of material properties

B6. STRUCTURAL DETAILS - What are the most important missing specifications, codes, standards and test methods for your industry sector?

1. Electrical and thermal conductivity
2. Customer and aviation authority driven certification requirements and acceptance criteria Relevance.
3. Joints
4. Linkages to DFX standards. Virtual validation, RCS optimised for aerospace
5. The issue is not codes and standards per se, but rather the regulatory framework across sectors that defines the validation/certification processes.
6. Cannot answer as not close enough to structure test. This has been driven by customer
7. Joints

1. NDT techniques for integrated structures
2. You cannot have these for structural tests
3. Equivalent methodology for the prediction of fire
4. No applicable to structural tests

1. Well defined standards matched to verification methods and assured data
2. Need much more emphasis here than at the coupon base. Missing quick standards and ones that can be achieved virtually
3. Parametric design tools and guidance in CAD. Standards for hybrid and mixed materials
4. Damageability and rapid diagnosis

1. Nothing specifically
2. Composite as a material and test methods related to composite

1. Inspection techniques
2. Hard to standardise these as the design detail could be anything and will be fairly specific to the application
3. These are specific to the application and need to be specific to that. The OHC, OHT, Bearing CAI aerospace type tests are simply not relevant
4. Everything and nothing. Again, details are often application-specific, so require special non-standard tests to be run
5. Again, everything and nothing. Such tests tend to be designed, agreed and executed on a project by project basis

1. Very hard to have anything other than a good practice guide for adhesive and bolted joints
2. Need a standard as to how to model structural details & which ones should be assessed depending on the application
3. Agreed virtual testing mechanisms

C1. FINAL PRODUCT - What are the most important missing specifications, codes, standards and test methods for your industry sector?

1. Built in test covering of NDE process and standards for composite manufacture
2. Inspection
3. Limited non-specific repair standards very limited
4. The issue is not codes and standards per se, but rather the regulatory framework across sectors that defines the validation/certification processes
5. Test method and acceptance criteria for fibre volume fraction of an actual component. Current methods like acid digestion do not take into consideration veils and binders. This goes back to the start as to what's achievable with a fabric
6. Inspection
7. Virtual validation/ certification standards
8. Design rules and acceptance criteria for large integrated structures
9. Inspection

1. Specification that allows in process inspection instead of post process inspection
2. Not applicable
3. Underpinning physics-based understanding of the fire environment linked to the key attributes of the system
4. Suitably qualified personnel who understand the physics of fire
5. Understanding thermal decomposition of composite materials and the relationship with the environment

1. Safety standards for damaged components. GO/NO GO
2. Missing repair standards relevant for auto
3. A practical compression test , based on stable geometry i.e. a tube or core stiffened panel
4. Crash damage NDT standards and specifications
5. Pragmatic design codes to interpolate/extrapolate properties based on variable fibre volume fracture
6. Simple and quick NDT for auto which is GO/NO GO
7. Regulations for inspection after crash as a first rather than replace and disposal
8. Safety standard for MOT that would force composite inspection either through NDT or condition monitoring. Simple enough that a garage can implement it and digitised to send results back to manufacturer

1. Nothing specific
2. Type of resin, test method and again the allowance of composites
3. Nothing specific
4. Inspection criteria and defect tolerance in final structure

1. Testing for adhesion and kissing bonds
2. Not so much definition of tests but the modelling that supports those tests to justify other untested load cases
3. Manufacturing quality assurance. Fitness for service assessments
4. Specifications WRT damage tolerance in tidal energy
5. In O&G end product testing is always an "as close as real life as possible" test and no real specs exist. Therefore, this is an agreement between the end customer and the certification bodies on agreement of knock-down factors
6. Definition of how you demonstrate repeatability in manufacture

1. Vessels covered by class are probably well covered. Others less so. But are they necessary? The industry is cost driven
2. Need more in relation to NDT in terms of appropriate (and validated) methods, definition of critical defect sizes for variety of structures and applications; guidance on methods that could be used; customisation of standard repair methods
3. Implicit in this discussion is a move from Equivalence to Performance which will be hard to sell to some conservative poorly informed regulators
4. Scarf repairs sometimes need to be tailored to suit the location and other features in close proximity to repair area -guidance on what is best practice would be useful; definitions of failure modes; how do you ensure the design intent is maintained?
5. We would therefore need guidance on what QA and NDA would be acceptable
6. Standard for how to define equivalence e.g. how to simulate defects and defect sizes for variety of scenarios using a validated process based on real life testing
7. Therefore, we need SQEP personnel at every level. This means that it is hard to establish accredited standards of training and curriculums. So clear qualifications at every level is critical to common composite standards
8. I believe BINDT have been looking into standardising operator skills for NDT methods - if this happened it would be another piece of the jigsaw

C2. REPAIR & NDE - What are the most important missing specifications, codes, standards and test methods for your industry sector?

1. Process standards in built supporting each stage of the composite process
2. Adhesives and joints
3. Multiple defects stacked through the thickness of the laminate are difficult to detect
4. Non-specific repair standards
5. The issue is not codes and standards per se, but rather the regulatory framework across sectors that defines the validation/certification processes
6. Guidance on repairs for different fabric technologies i.e. repair of NCF resin infused vs repaired woven
7. Many hours of work have been put into SAE CACRC
8. Thick composites
9. Awareness of the CACRC repair group
10. Classification of acceptable defects across multiple application scenarios
11. We need guidance for qualifying new NDT methods
12. Composite to metal joints
13. Fastener free repair
14. We need guidance for on the fly process control inspection

1. CT scanning for large parts with the resolution required for finding minimum defect sizes

1. Go/no go for repairs post accident. Must be simple and quick to assess
2. Standard for provision of repair data from OEM
3. Clarity of service loads and local allowable safety factors when the repairer is not the original design authority

1. Test methods for thick composites

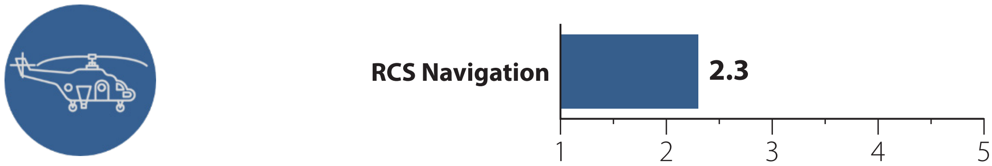
1. Technology that allows extension on the life of repairs
2. There is virtually no definition of NDE techniques for composites in the O&G sector
3. NDE in manufacture and in service
4. Few standards exist for NDT and guidance on repairs for O&G products and needed

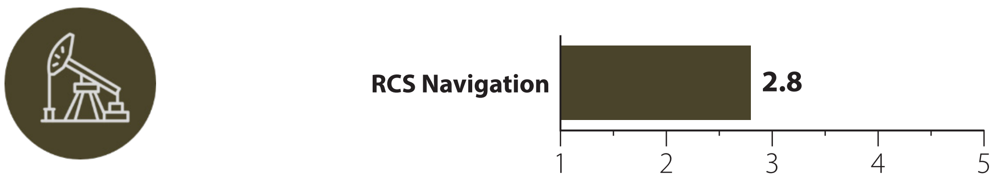
1. This is improving but I'm not sure there are standards. RNLI have developed their own methods for their own structures/laminates
2. Standard for repairing using novel / emerging methods - what extra validation would be needed?
3. A common cross sector qualification plan
4. A uniform taxonomy regarding NDE of composite structures needs to be developed - what is a defect when does a defect become damage - when is repair necessary - not just understanding the defect/damage shape/extent but its impact on performance
5. How to assess longevity / robustness of repairs i.e. how do you life a repair?
6. How do you factor in novel materials e.g. self-healing composites

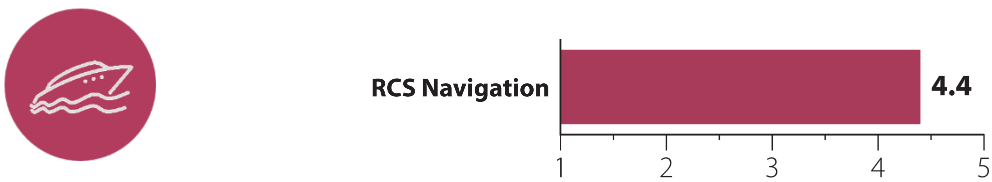
C3. How easy is it to navigate the required regulations, codes and standards for approving a product in your industry sector?

(rate 1 (very easy) to 5 (very difficult))

25 responses



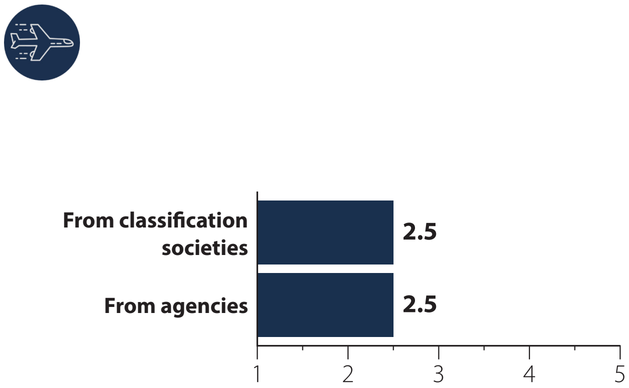


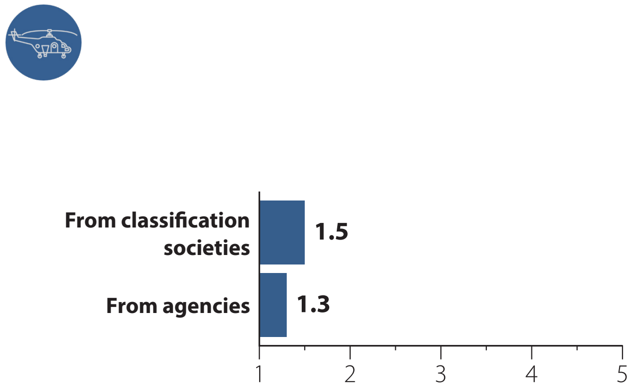


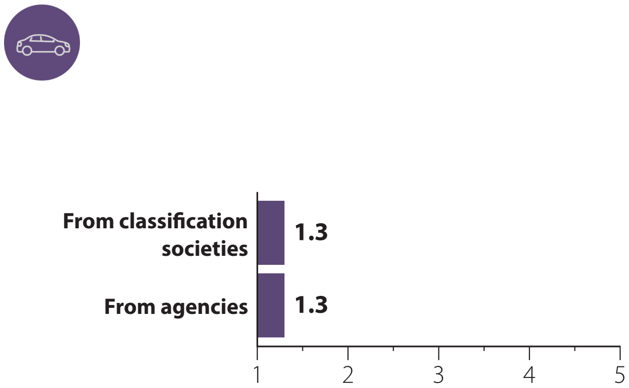
C4. What is the level of support related to practical aspects of the product approval process you currently receive from agencies and/or classification societies in your industry sector?

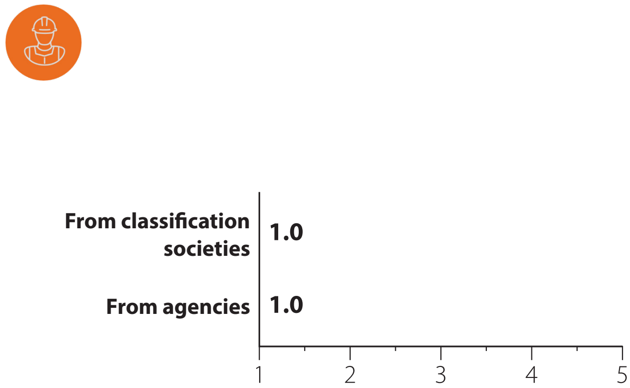
(rate 1 (low) to 5 (high))

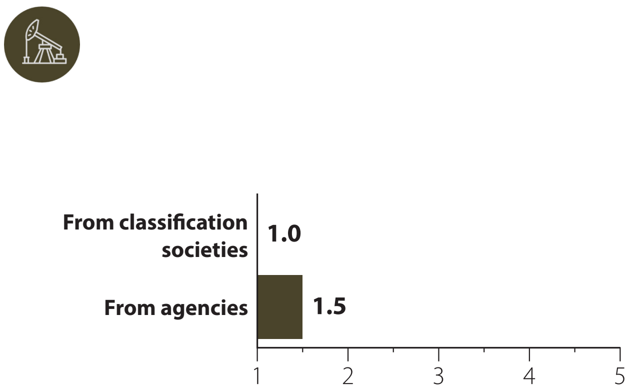
18 responses

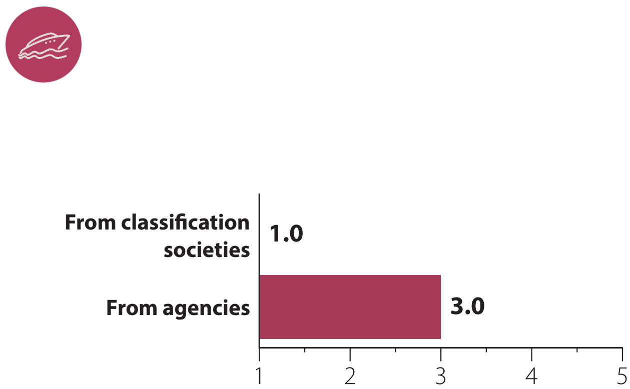












C5. What type of support will benefit your organisation?

1. Agreed OEM and supplier standards
2. RCS for new manufacturing processes that require in process verification
3. Generic support which can be used opposed to OEM specific

1. Data bank
2. Clear lines of communication and identification of the responsible individuals
3. Clear technical guidelines

1. Materials and processes training for non-composites experts
2. Technology support to actually meet the standards

1. Guidance through the certification process by suitably SQEP

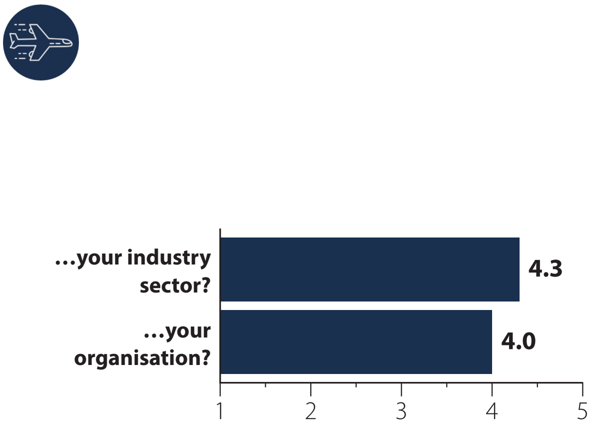
1. Engaged third party approved and end users
2. Very new to area of application. Starting at general awareness
3. Certification agencies have a mixed level of composites knowledge. DNV is high and they also are a test house, which gives them the knowledge but could represent a conflict of interest in specifying them

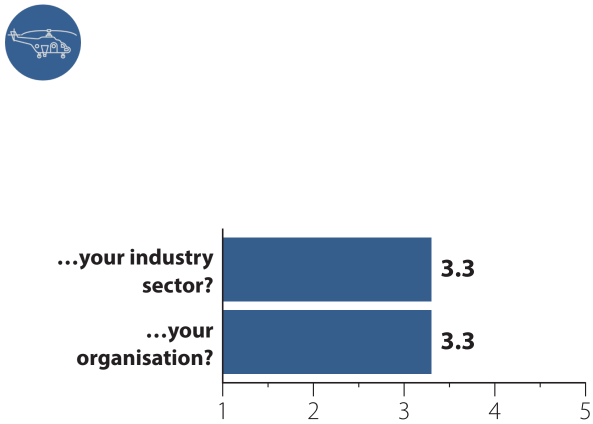
1. Online tool for standards selection - linked to from several sites to enable ease of access
2. Better understanding and knowledge by the relevant bodies. Composites knowledge is still limited in most
3. Ideally having a single point of contact or website that gives all the information at all stages of the validation chain
4. Working with regulators in a form of mentoring system similar but not so rigorous as the Nuclear industry would save companies time and cost
5. A single place where independent advice could be provided on NDE and the way through the regulation procedure
6. Having a guidance document that contains all relevant information
7. Central orchestration of data

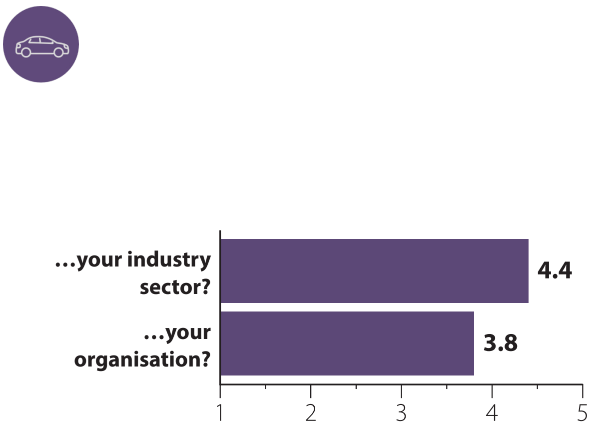
C6. A virtual tool for providing a clear linkage between regulations, design codes, specifications and standards will benefit…

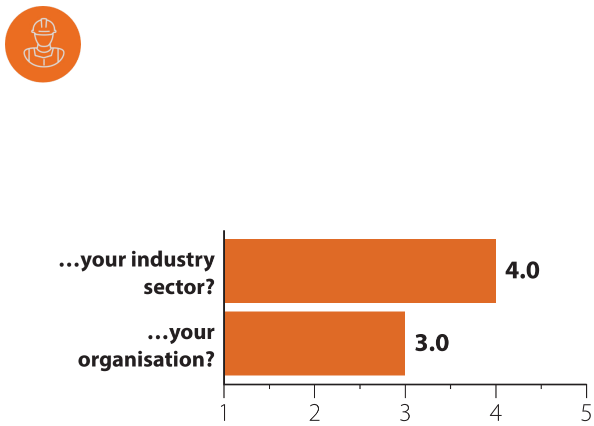
(rate from 1 (strongly disagree) to 5 (strongly agree)

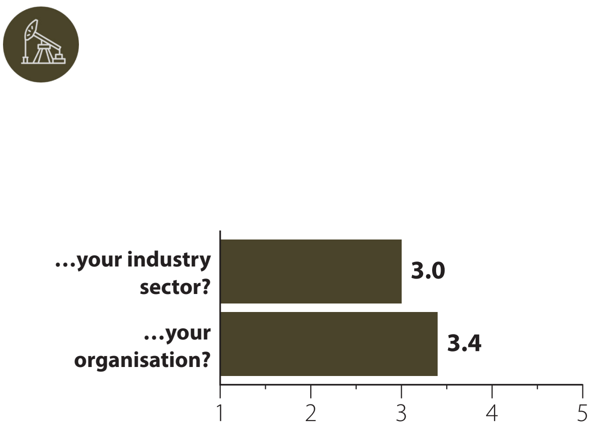
25 responses

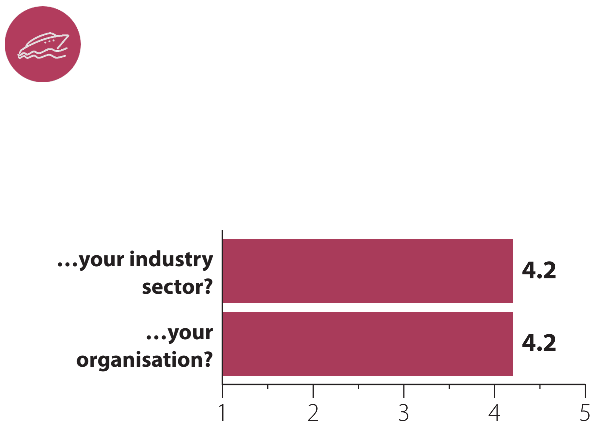








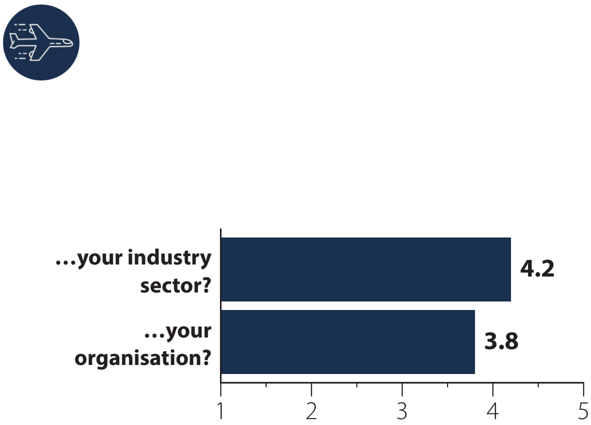


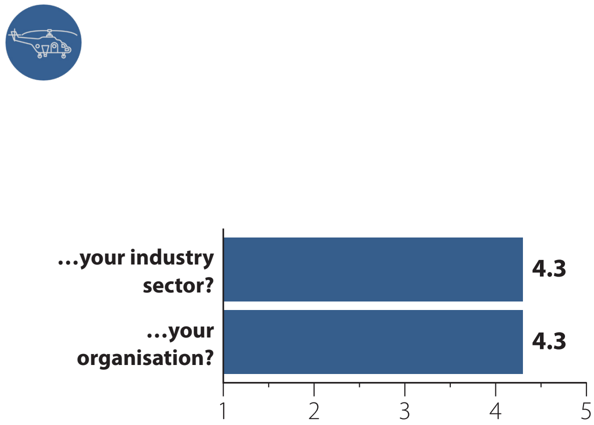


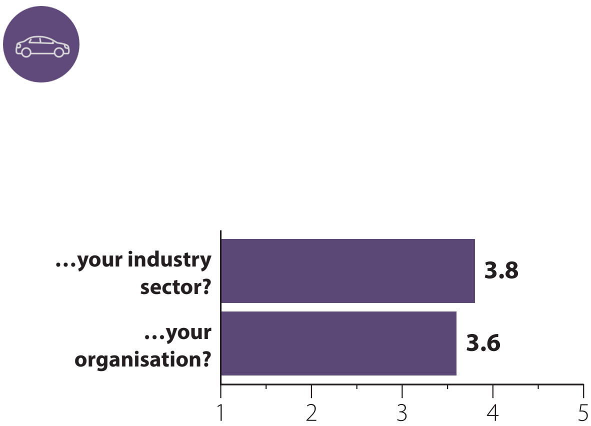
C7. A mentoring scheme providing guidance, developed in close collaboration with regulators, agencies and classification societies will benefit…

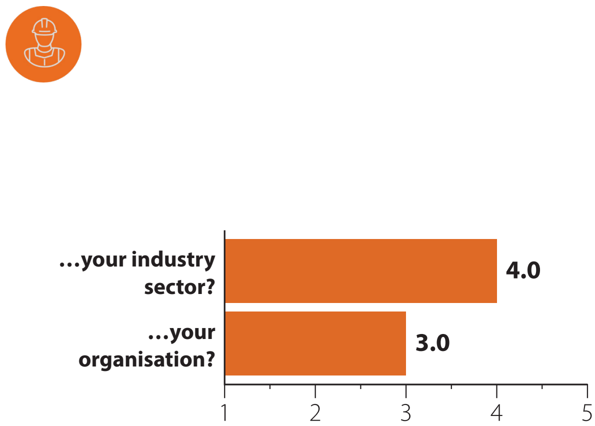
(rate from 1 (strongly disagree) to 5 (strongly agree))

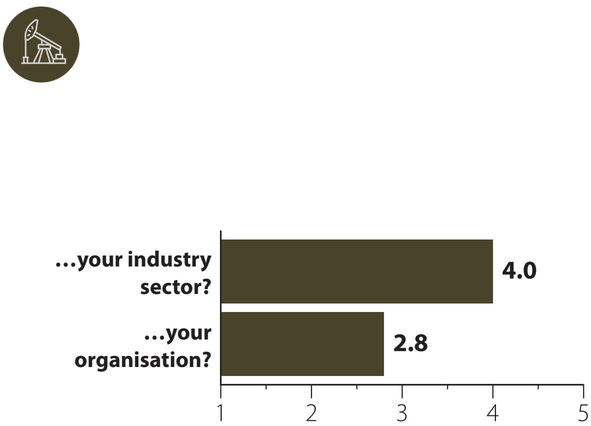
24 responses

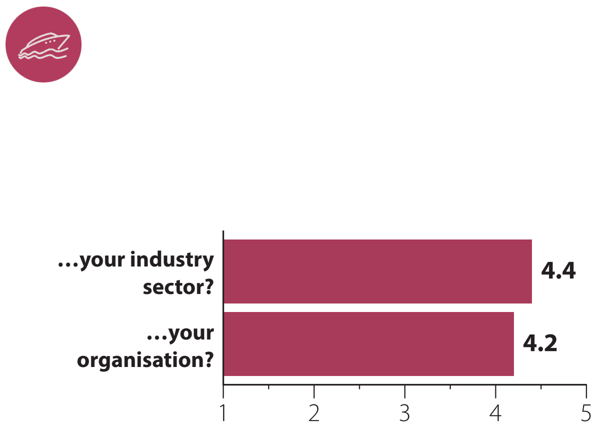








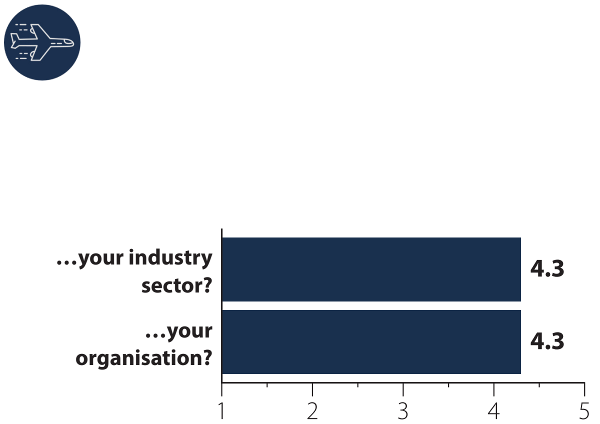


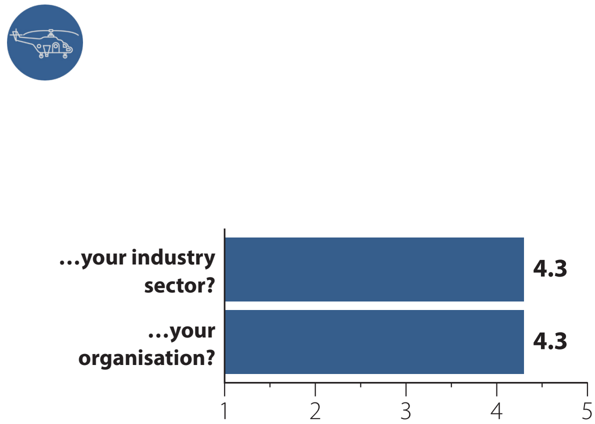


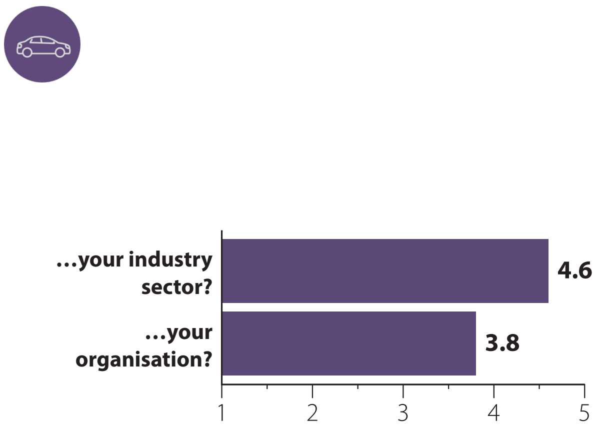
D1. Do you believe that a shared composite materials database will benefit...

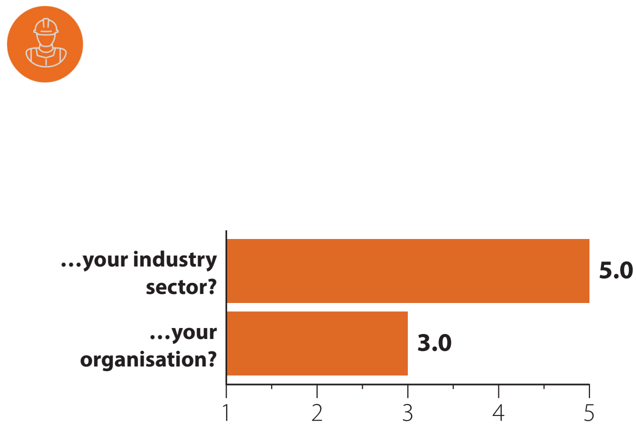
(rate from 1 (strongly disagree) to 5 (strongly agree)

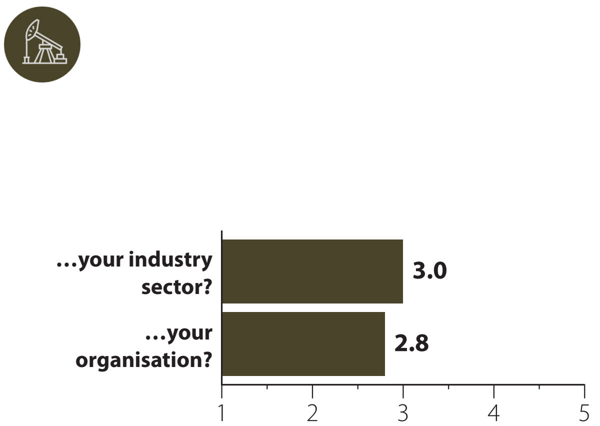
26 responses

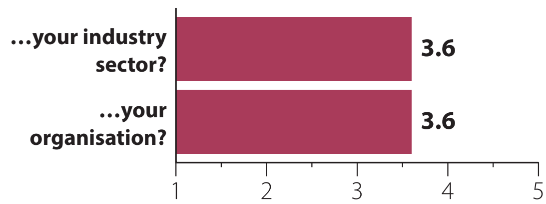












D2. What type of data needs to be included in such a shared database?

1. Everything
2. Non-design specific data (laminators and laminate)
3. Specific formulations for optimised manufacturing processes
4. Basic mechanical and Physico-chemical
5. Basic material data to support SMEs, yes; but to support final parts or more complex characteristics, no. All companies must be aware that more work (testing) will be required
6. Bolted joint data (generic)
7. All parameters to make an informed choice against the product definition!
8. Source of the material
9. Method of manufacture
10. Physio-chemical properties

1) Material properties that can be used to derive design allowables
2) Free validated relevant data
3) Laminate level experimental and validated failure models

1. At least 2 levels generic to help with M&P selection; 2nd level to help with design
2. Two levels of data- generic groupings around material types and second level specifics to inform design and also retrospectively create a passport for end of life or crash validation of original performance

1) Basic material property data
2) FST (Fire, Smoke and Toxicity)
3) High strain rate, damage tolerance and fatigue data
4) Environmental data

1. Difficult to do so given competitive advantage and specifics of service
2. In O&G there is little commonality with equipment manufacturers to need a common data set. Often material selection, manufacturing method and IP in the test data they pay for is a market differentiator

1. Materials allowables. Generic resin matrix information. Laminate properties for some common laminates with different resins, and fabrics for comparison
2. Standard material properties for design, processing requirements, variability of properties, effects of ageing on properties, equivalent /closely associated materials
3. Data on qualified materials and certified substructures and common routes through the regulatory processes
4. Materials, processing, NDE, repair
5. Typical failure modes, critical defect sizes, composition for disposal purposes, recycling options
6. Damage repair
7. Mentoring. Qualifying material outside a specific product. Using the information to inform through life costs in the form of repair, maintenance. Shared innovation between sectors
8. Shared approved manufacturing process which would be approved to move to the next level of testing at component level

D3. What are the challenges in generating and using common materials data in your sector?

1. Material Supplier commitment to results and concept of database
2. Standards, IP, funding
3. IP
4. IP, commercial agreements, protection of know how
5. IP challenges but I believe this would benefit technology development and force price competition
6. The database creation and maintenance will be more critical than generating and using the database, that is a second step

1. Funding & ongoing database management
2. Money
3. Provenance of data; lack of data for fire modelling and thermal decomposition and heat transfer and definition of the thermal environment

1. Set the fidelity (appropriate for different sectors) and the scope of the data against agreed standards vs marketing data
2. Cost
3. Context on manufacturing process can massively change properties so needs to be an informed database
4. IP and competition
5. Multiple layups, resins, processing conditions

1. Making sure that material manufacturers appreciate generic properties are not their main source of IP. It is the manufacturing process and products that gives them competitive advantage
2. Benefits of cost sharing for material qualification vs testing being done individually, per manufacturer or product. And realise competing with much larger industries, concrete and steel and so is more about gaining more of the market

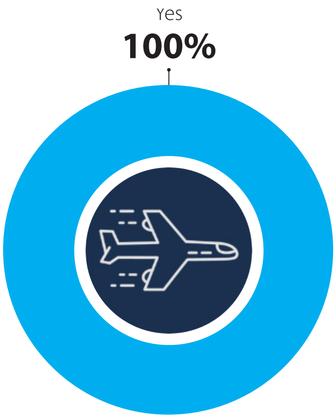
1. So many suppliers, different service conditions, are you buying a service with a solution or just the individual components
2. IP
3. Identifying a product or application where the basic data set would be of sufficient use to show the benefit is difficult

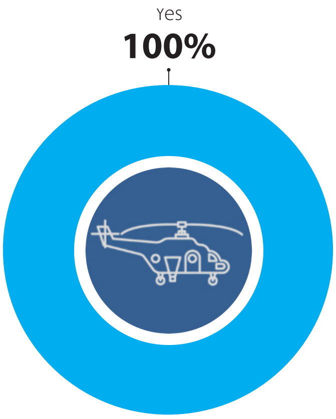
1. IP
2. Sustainable model to maintain the database
3. Persuading supplies to release data. Standardising format and selection of data presented
4. IP, all currently tested to different standards, including new and emerging materials
5. Inexplicit requirements
6. Poor regulator education
7. Proprietary information

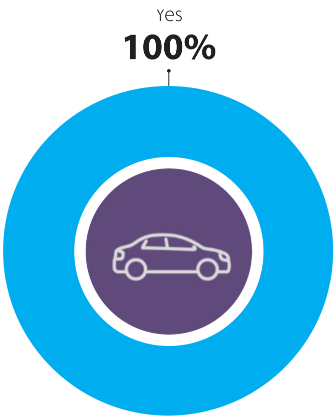
D4a. Do you believe that the presented shared data generation model is viable for your industry sector?

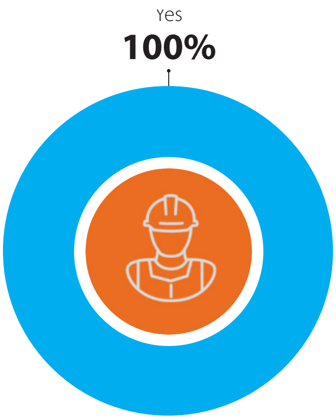
(yes, no)

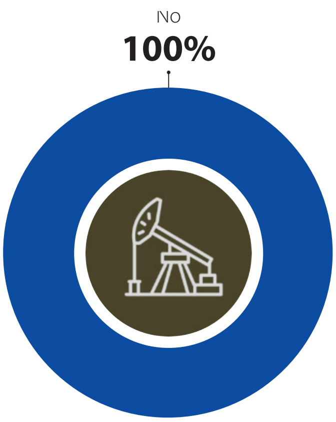
20 responses

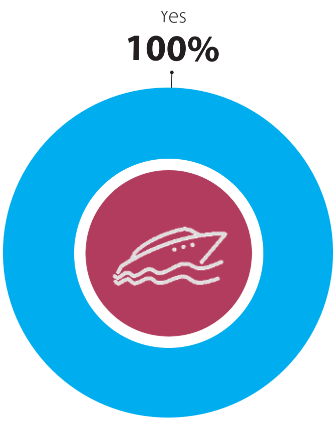












D4b. If No, how can it be improved?

1. Question: is a made database the only tool? A specific web AI search to populate a database could be an alternative

1. Require a different multidisciplinary approach for the fire environment

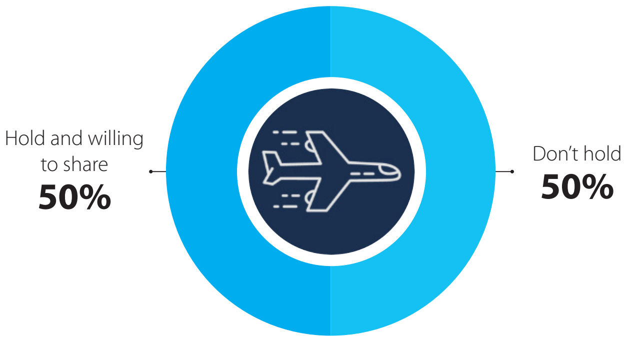
1. It is too early in the uptake of composite materials in O&G sector
2. Covered in our table discussion
3. The use of composites is still new to the industry so time and increase in use is needed

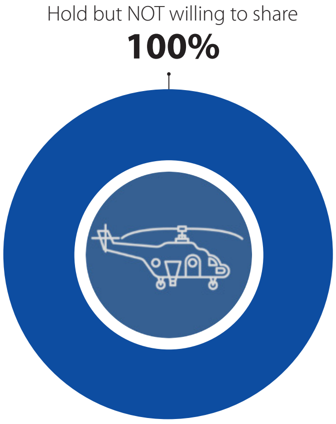
1. Database would work to a certain point but there is still a requirement to test in the facility and using the equipment and processes where it will be used in production. This is from a warranty perspective (foot note to do so on data sheets)
2. Look to more use of virtual regulation, but also from a quality assurance perspective

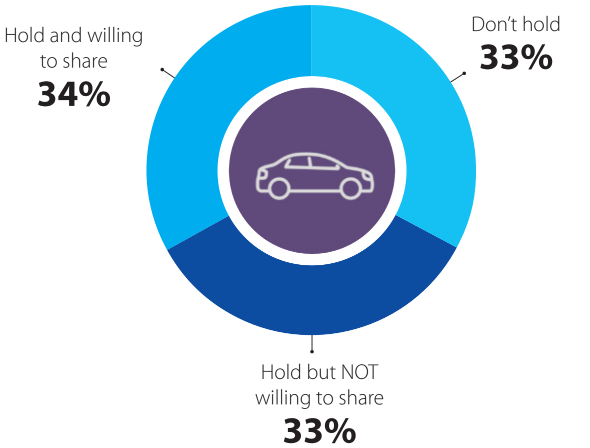
D5. Do you already hold any composite materials data that you are willing to share in a database?

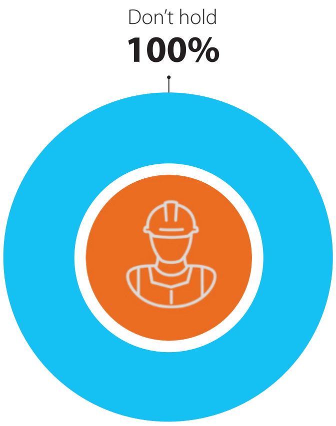
(Hold and willing to share, Hold but not willing to share, -Do not hold)

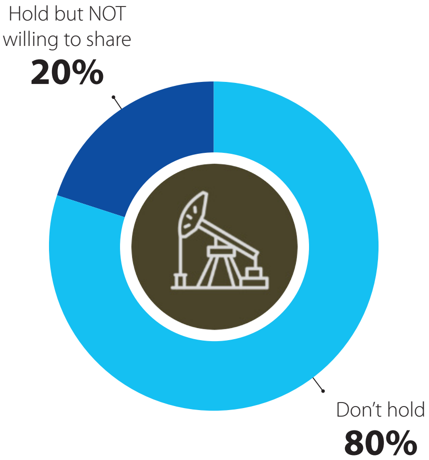
22 responses

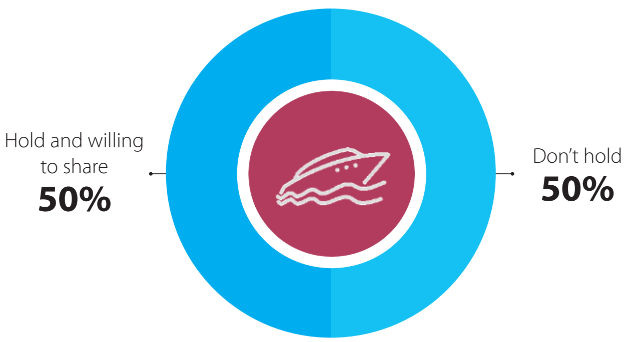












D6. If you hold and are willing to share, what is the type of data?

1. Varied
2. Material suppliers tend to own the data. IP issue
3. Cured properties not constituent properties

1. Build block

1. Mechanical test data for thermoplastic braided materials

1. Laminate test data; sub component test data. There may be more. Before sharing we'd need to understand the implications of doing so
2. Information on NDE, composite materials properties, novel testing methods, integrating test data models
3. Full scale test data - but less likely to wish to share other than with targeted individual organisations

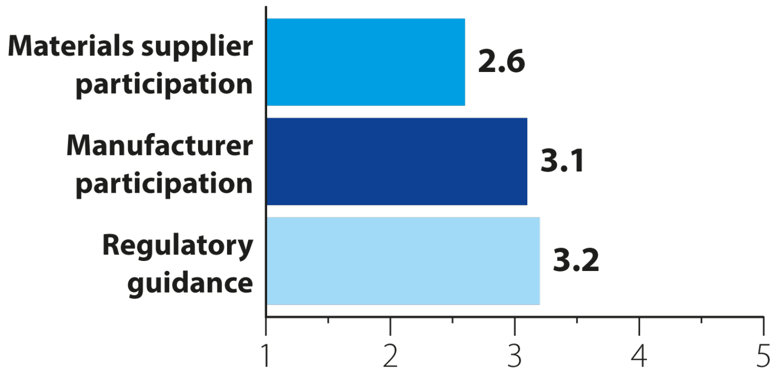
D7. As a materials supplier would you be willing to participate in a programme that will qualify your materials and populate a shared database?

D8. As a manufacturer would you be willing to participate in a programme to populate a shared database while validating your manufacturing process?

D9. As a regulatory authority would you be willing to guide a materials qualification programme?

(rate from 1 (strongly disagree) to 5 (strongly agree))

28 responses



6 Appendix 2: National Centre for Advanced Materials Performance (NCAMP)

The National Centre for Advanced Materials Performance (NCAMP), a department within the National Institute for Aviation Research (NIAR) in Wichita State University, USA, is a good example of a close collaboration between regulators and industry to share data enabling faster uptake of composites. NCAMP has its roots in the Advanced General Aviation Transport Experiments (AGATE) programme[29]. AGATE was a consortium of NASA, the FAA, the general aviation industry and several universities aiming to develop affordable new technology, industry standards and certification methods for general aviation aircraft. It was a public/private cost-sharing partnership, launched in 1995 and ended in 2001. NIAR oversaw the AGATE Materials Working Group. The AGATE methodology and resulting database shifted the major responsibility for qualification and testing from the aircraft manufacturer to the material supplier, with the shared database allowing a manufacturer to select a pre-approved composite material system through a smaller subset of testing, known as equivalency. The materials accepted into the shared database required that the raw materials be manufactured in accordance with process control documents and material specifications, which impose control of the key physical, chemical and mechanical properties. The DOT/FAA/AR-03/19[30] report written for AGATE evolved into an FAA policy (ACE-00-23.613-01)[31]. NCAMP was announced in 2005 aiming to refine and enhance the AGATE composite material property shared database process to a self-sustaining level and to provide a collective means for continuously monitoring approved materials, to ensure their stability over time. To achieve its aims NCAMP works in partnership with Composite Materials Handbook CMH-17, SAE International and ASTM International as well as the FAA and the U.S. Department of Defence.

The shared database benefits directly: (a) the aircraft manufacturers, who instead of qualifying an entire material system, they can pull a system from the NCAMP database, prove equivalency and gain FAA certification, quicker and cheaper; (b) the materials suppliers, who can work with NCAMP to qualify material systems without having to be linked to an ongoing aircraft certification program, thus getting their material out into the market via a public forum with generated allowables and FAA approval and (c) the public that can access the NCAMP data or the specifications without any fee.

The most important aspect of NCAMP's operational model is that it is authorised through a self-delegation certificate from the FAA and EASA to qualify materials for use in aircraft structures, without the need for these materials to be assigned to an official aircraft program. This frees up suppliers to develop a range of materials and co-fund their qualification with a number of potential future buyers. A capability that is very appealing to a coalition of smaller manufacturers that cannot afford the full qualification cost of a material. Moreover, NCAMP has a very flexible and agile operational structure which enables fast decision making, particularly when it comes to working with industry. The operational model allows NCAMP to consult industry on the material qualification and certification process. Their SQEP often guide/mentor companies (particularly the smaller companies) through the process efficiently. Finally, inward industrial investment to the area and the University as well as early career training programs that are aligned to the operations attracts further investment from Kansas State Government.

29. https://www.nasa.gov/centers/langley/news/factsheets/AGATE.html
30. http://www.tc.faa.gov/its/worldpac/techrpt/ar03-19.pdf
31. https://www.govinfo.gov/content/pkg/FR-2000-06-13/pdf/00-14880.pdf

7 Appendix 3: Standard Qualification Plan (SQP) for composite materials

ISO 20144[32] , which was published in July 2019, has been prepared to provide suppliers, designers, end-users and regulators of fibre-reinforced polymer composites, with an initial qualification framework aimed at reducing the substantial costs involved in qualifying materials against different bespoke company specifications, with varying degrees of commonality. Indeed, the cost associated with qualifying materials can prevent the use of new materials in certain applications or even the development of new materials themselves. In addition, designers and end-users often find that appropriate data for materials selection and preliminary design are not readily available or comparable. Widespread use of this document for initial qualification is intended to lead to a reduction in qualification costs and increased availability of reliable and robust materials data across a wide range of sectors and applications. It provides for more detailed qualification procedures, including calculation of B-basis design allowables. Material suppliers could adopt this procedure for obtaining the required data to support initial material selection and qualification and to supply the specified data at the same time as release of the material evaluated. This will greatly extend the availability of consistent and comparable materials data based on agreed individual, international test methods to support users, fabricators and regulators.

Validation of the framework in ISO 20144 has been undertaken for thermoset systems, which are currently the most abundant and established matrix-based systems. However, it is accepted that the calculations, and therefore the property data, can also be applied to similar thermoplastic matrix-based systems. Therefore, thermoplastic matrix-based systems can also be covered by the document, providing the underpinning test method's technical aspects are met regarding failure mode etc.; with the exclusion of property tests specifically designed for uncured thermoset materials, where indicated.

32. https://www.iso.org/standard/67148.html

8 Appendix 4: Authors

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Stefanos Giannis is a Principal Research Scientist in the Advanced Materials Characterisation group at NPL. Since 2018 he has led the Regulations, Codes and Standards work to support and enhance the composite materials regulatory infrastructure. He has 20 years postgraduate experience in polymers and polymer composites in testing, inspection and certification. He is a Fellow of the Institute of Materials Minerals and Mining (FIMMM) and has an associate teaching position at University of Surrey.

Michael Gower

Mike Gower is a Principal Research Scientist and Science Area Leader for Materials Testing within the Advanced Materials Characterisation group at the National Physical Laboratory. Mike is responsible for the development of metrology to underpin the use of composites as multifunctional materials to enable optimisation of the processing and in-service performance of composite structures. He has 24 years of experience in mechanical testing, physical analysis, characterisation, non-destructive testing and finite element analysis of composite materials. Mike holds a degree in Aeronautical Engineering and an MSc in Composite Materials from Imperial College

Professor Graham D Sims

Prof. Graham Sims is a NPL Fellow (Composites and Material Systems) and a Visiting Professor at University of Surrey. He established and chairs the Regulations, Codes and Standards Working Group under the Composite Leadership Forum. Dr Sims has been involved in international standards for composites for 20 years, drafting as Project Leader more than 20 ISO standards and convenes ISO/TC61/SC13/WG2 on Laminates and Moulding Compounds – mainly mechanical test methods. He is a past Chairman of the pre-normalisation G15 VAMAS (Versailles Project on Advanced Materials and Standards) for validation of test methods and determination of precision statements in standards.

George Pask

George Pask is the Group Leader for Advanced Materials Characterisation at NPL, responsible for operational management of the team and projects. George joined the team in 2017 and has over 10 years' experience managing scientific projects across different technical disciplines within industrial and public sectors.

Gareth Edwards

Gareth is a Strategic Business Development Manager at NPL working to develop collaborations across industry, academia and government, using the extraordinary science and engineering undertaken at the NPL to help accelerate the UK manufacturing industry's growth and competitiveness. He is a Chartered Materials Engineer with over 20 years of experience in test, evaluation and programme management, particularly within the marine, nuclear and automotive sectors.