2016

Final Report

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Figure on front cover: The X4 is one of three new Airbus Helicopters in development at Donauwörth. Retrieved on 2016-10-10 from http://www.compositesworld.com/cdn/cms/eurocopterx4exterior-480px.jpg

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Acknowledgements

A big thank you to Dr. Kjelt van Rijswijk for sharing his knowledge, experience and passion. It was this passion for innovation that triggered a search for unconventional solutions.

Thank you also to MC and AN (who wish to remain nameless) who provided the first intimations that conventional approaches to training had not worked in this sector and would not work in this sector in its current state of evolution.

Disclosure

In terms of this study I need to make the following disclosure.

I have been interested in the field of fibre-reinforced plastics and composites since my entry into the plastics industry in 1981. Prior to that I had been a school teacher. One of the first lectures I had to prepare was on FRP and the new field of advanced composites. Because of my interest in aviation and motor sport I went well beyond the somewhat simplistic content of the lecture material and focussed on the, then, new developments. My CEO at the time was flabbergasted –"Where did you get all this stuff?"

Later I developed a manual and lectured on a course covering plastics raw materials which included many of those polymers used in composites. I attended a supplier course on unsaturated polyester resins in the mid-1980's (Trevor Snyman at NCS Resins) and subsequently was involved in and supervised the development of a course on fibre reinforced plastics.

I also kept up to date with developments not only in this field but in the field of polymers in general. Over the same period and subsequently I have visited manufacturing plants and laboratories and seen at first hand the manufacture and testing of composites, including advanced composites. Because of my interest in the field I have constructed components in a bricolage fashion using these techniques, e.g. a Masonite-cored, nylon net curtain reinforced Pratley's quick set glue to manufacture a base for the seat of my racing motorcycle.

The contents of this study have been shaped by these experiences.

Abbreviations and Acronyms

AMTS	Advanced Manufacturing Technology Strategy
CPD	Continuous Professional Development
dti	Department of Trade and Industry
FET	Further Education and Training Band on the NQF (Levels 2, 3 and 4)
MBCC	Mandela Bay Composites Cluster
MERSETA	Manufacturing, Engineering and Related Services Sector Education and Training Authority
MSDS	Material Safety Data Sheets
NAMB	National Artisan Moderation Body
NQF	National Qualification Framework
OFO	Organising Framework for Occupations
QA	Quality Assurance
QCTO	Quality Council for Trades and Occupations
SABPP	South African Board for People Practices – a professional body for Human Resources Practitioners
SASRIA	South African Special Risks Insurance Association
SETA	Sectoral Education and Training Authority
SMME	Small, Medium and Micro Enterprise
SWP	Standard Work Procedure developed by AMTS
TETA	Transport Education and Training Authority
WSP	Workplace Skills Plan

Glossary of key terms used in this research project

The section that follows provides a glossary of the key terms that we have used throughout the project.

Advanced Composites Industry in South Africa

A branch of the fibre reinforced plastics industry which produces components and structures which combine high performance resins, fibres and other components into products designed and engineered for demanding and safety-critical applications.

Open (Digital) Badges

Open Badges are visual tokens of achievement, affiliation, authorization, or other trust relationship sharable across the web. Open Badges represent a more detailed picture than a CV or résumé as they can be presented in ever-changing combinations, creating a constantly evolving picture of a person's lifelong learning.

Pasted on 2016-10-30 from https://openbadges.org/>

Skills Profile

A succinct summary of knowledge, competencies and attributes required for each occupation.

"Job" and "Occupation"

ISCO-08, which is the most recent version of the International Standard Classification of Occupations developed by the International Labour Organisation (2008), describes the distinction between "job" and "occupation" as follows:

- **Job:** A set of tasks and duties performed, or meant to be performed by one person, including for an employer or in self employment.
- **Occupation:** A set of jobs whose main tasks are characterized by such a high degree of similarity (ILO, 2012:11).

Polymer Composite

A fibre reinforcement embedded in a polymer either thermoplastics or thermosetting

Value Chain

The term "value chain", as used in the project, was originally developed by Porter (1985) in his book *Competitive Advantage: Creating and Sustaining Superior Performance*. The three phases of Plastics Chamber research process used Porter's concept of a value chain to represent the steps involved in converting raw materials into a finished product in various sub-industries. At each node in the value chain there is usually a job associated with specific equipment and/or tasks. Wikipedia defines a value chain as "a chain of activities that a firm operating in a specific industry performs in order to deliver a valuable product or service for the market". (Wikipedia, 2014)

Nodes in the Value Chain

These are points in the value chain where value is added to inputs and that may be associated with a job or jobs which require a particular skills set.

Chapter 1 – Introduction

The focus of this study is skills in the advanced composites industry.

Before discussing advanced composites it is useful to understand the concept and history and application of composites in general and polymer composites, in particular.

This introduction gives a brief overview of composite materials in general, the history and types of polymer composites, some terminology related to polymer composites and a description of the advanced composites industry.

What are composite materials?

*A **composite material** (also called a **composition material** or shortened to **composite** which is the common name) is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components.* (Retrieved on 2016-06-30 from https://en.wikipedia.org/wiki/Composite_material)

Early mankind combined mud and straw to make stronger bricks. The mud acted as a binder and straw provided strength. The mud or binder is generally termed the matrix and the straw is termed the reinforcement or reinforcing material.

In today's world there are many applications of this concept, including composites based on:

- cement (mortar, concrete)
- metal
- ceramic
- polymer (plastics) composites.

History of polymer composites

Fibres and polymers have been intimately bound together (pun intended) since the very first commercial plastics were developed.

Bakelite, the trade name of one of the first commercial plastics in the early 20th Century was a composite material consisting of phenol formaldehyde and asbestos fibres. The phenol and the formaldehyde reacted together under pressure and heat to polymerise. The reaction embedded the short asbestos fibres in the newly formed polymer. Bakelite was used to mould and mass produce a variety of functional and decorative components and products.

Phenol formaldehyde is a strong, rigid but brittle material. It was also heat resistant, didn't conduct electricity and had good adhesive or binding properties. By combining it with short fibres it becomes stronger and less prone to cracking or disintegrating under load and has improved heat resistance.

What are polymers?

As more polymers were developed the range of polymer composites increased and so too, the range of terms used in the industry. This section briefly summaries some of the key terminology related to this study.

Note: The explanations have been deliberately kept simple – this is not intended to be a text book.

Polymers are formed when under the right conditions single molecules (monomers) react and form very large molecules.

Polymers go through a **plastic phase** – a phase during which they can be shaped. Hence they are called plastics.

There are **two broad types of polymer**, thermosetting and thermoplastic.

Phenol formaldehyde is a **thermosetting** polymer. Thermosetting materials undergo a chemical change when heated. The material first flows, then starts to harden as the chain-like molecules begin to cross-link and sets hard as a three-dimensional molecular matrix develops. The change of state is similar to cooking an egg and it is irreversible.

Other polymers form chain-like molecules when polymerised. If these polymers are heated the molecular chains can move relative to one another. This means that when heated they soften and can be shaped, and then when they cool, they harden again. This process can be repeated – the polymers behave like candle wax and are called **thermoplastics**.

The following section provides a brief overview of various types of polymer composites and the related terminology.

Volume moulded reinforced plastics

Since the development of Bakelite many of the newer polymers are thermoplastic. After polymerisation and before they are moulded thermoplastics polymers can be combined with a range of short fibres, such as glass, or fillers such as talc.

They are then melted, formed and cooled into sometimes very complex shapes. The moulding process is a mass-production process and the composite materials are known as *reinforced thermo-plastics*, but are mostly shortened to *reinforced plastics.* Reinforced plastics are often used to replace metal components in demanding applications such as under-the-hood engine components in motor vehicles such as radiator end-tanks, pumps and electrical products.

Thermosetting resins can also be used for moulding components in high volumes. Unsaturated polyester resins are prepared as bulk or sheet moulding compounds that are heated and shaped in compression moulding presses. These products are mostly used for manufacturing structural components such as large electrical housing or motor vehicle body panels.

This study is not concerned with this class of materials or these manufacturing processes.

Low and intermediate volume fibre-reinforced laminated thermosetting plastics

During the middle of the 20th Century newer manufacturing processes were developed which could produce long glass fibres. These fibres could subsequently be made up into a wide range of forms such as fibre mats, rovings, woven rovings, and woven and knitted 2 and 3-dimensional fabrics.

Simultaneously new types of thermosetting polymer, particularly unsaturated polyester resin, were developed. The fibres are laid into a mould and the laminator wets-out the fibres with a liquid resin[1]. A chemical within the resin initiates a chemical reaction and the resin hardens i.e. the polymer chains form a cross-linked or three dimensional molecular matrix. This hardening phase, during which heat is given off, is referred to as the curing process. The application and curing process can be repeated to build up layers of resin and fibre and the finished product is referred to as the laminate. Only one half of a mould is required so that there is a finished and a rough side to the moulding.

With this method of manufacture it became possible to produce much larger parts such as vehicle panels, vehicle bodies (e.g. beach buggies), structural aircraft components and boat hulls. The cured resin adheres to the fibres and holds them in the final shape of the product. These polymer composites are also known as *fibre-reinforced plastics* (FRP) or *glass-reinforced plastics* (GRP). Several laminates can be combined using more resin and glass.

FRP components are generally stronger and lighter, are less prone to chemical degradation or corrosion and can be less expensive to make. The lay person commonly calls these composite materials *fibreglass*. Fibreglass is used for a variety of industrial applications. Some of these include chemical plant, vehicle body parts, one-piece swimming pools, boat hulls, surf boards and other sporting goods.

This type of manufacturing process is relatively simple and has a low barrier to entry. The industry describes such new entrants as the “bucket-and-brush brigade”. It also attracts the hobbyist. They rely on material suppliers for information and guidance and several suppliers run courses for both the new entrants and the staff of more established suppliers.

To increase output various parts of the manufacturing process are automated and increasingly computer controlled.

The manufacturing process does, however, present some challenges. The material and the component itself are made at the same time. Similar components in metal are generally made in a two-stage process. First the metal sheet or profile is made (i.e. the component is prefabricated). Then it is cut, shaped and riveted or welded into the final product. The metal in the final product is the same as the metal in the prefabricated component. The metal

[1] In British English resins are generally liquids. In American English all plastics raw materials are called resins.

sheets and the rivets are known quantities. If they meet the specification prior to the fabrication process they meet the specification after the fabrication process. Inspection, quality control and problem solving are relatively simple. Product faults are also generally visible.

In contrast, faults may be “baked into” the FRP component and not be visible to the naked eye. Moisture or dust on the reinforcing fibres can cause delamination at a later stage. This makes inspection and quality control and problem solving more difficult. Testing processes, especially non-destructive testing processes, become essential. Faulty components have to be scrapped completely and the resin or glass cannot be recycled.

However, rigorous control of the manufacturing process results and the industry’s ever-growing experience yields products which work as designed. FRP products excel where flexibility of design and manufacture, high strength to weight ratios, corrosion, electrical and chemical resistance, and low life-cycle costs are important.

The study is also not concerned with this class of materials.

Advanced composites

Advanced composites industry is a short-hand term for a particular branch of the fibre reinforced plastics industry. This branch produces components and structures which combine high performance resins, fibres and other components into products designed and engineered for demanding and safety-critical applications.

With the advent of more specialised resins and fibres, new high-performance composite products were made possible. These are often termed space-age materials because they were developed as part of the space exploration programmes in the 1960s. They were also termed *advanced composite, advanced polymer matrix composites, high-performance composites* and so on because of their superior properties relative to traditional materials and fibre reinforced plastics. For the purpose of this study we will use the term advanced composites.

The advanced composites industry operates at the cutting edge of the FRP industry producing and repairing high-performance parts and components for the aerospace, aircraft manufacturing, automotive and vehicle manufacturing, energy production, in particular wind energy, and ballistic (bullet-proof) wear industries.

Advanced composites generally use epoxy resins and carbon or aramid (Kevlar) fibres. Continuing developments in the manufacture of resins, e.g. high temperature resins and biopolymers, and fibres e.g. natural fibres and nano-tubes, mean that the industry continuously adapts designs and the manufacturing process to develop new products.

Advanced composites components are also engineered to meet the requirements of the manufactured product in a range of different ways:

1. Resins can be formulated to meet specific requirements
2. Fibre reinforcement can be constructed in a wide variety of shapes and forms including tows, strands, woven and knitted materials, two-and three dimensional fabrics
3. Using fabrics pre-impregnated with resin (prepregs)
4. Including foam and honeycomb core materials (sandwich construction)
5. Including other structural components such as tubes, spars, metal fittings or sheets.

The range of manufacturing processes also varies according to the requirements of the end-product. Manufacturing processes include:

1. Wet layup (as for FRP)
2. Hand layup and vacuum bagging
3. Hand layup and resin injection moulding
4. Spray-up processes (hand-operated and automated systems)
5. Resin transfer moulding, with or without vacuum
6. Oven (heat) or autoclave (heat and pressure) curing

A helicopter blade is a very good example of an advanced composite product. A single blade consists of a number of different components. At the centre, for a large part of the blade, is a honeycomb core. Towards the tip of the blade the honeycomb core is replaced by one of foam. Prepregs are cut into special shapes and laid down in layers, with each layer in a slightly different direction, the leading edge is finished in a special prepreg which is more impact resistant than the other layers. Metal inserts are placed at the end of the blade for mounting purposes. Sensors such as strain-gauges, pressure transducers, accelerometers and thermal sensors are built into the various layers. The blade is a complex shape and its profile varies along its length. More advanced blades include devices which can change the shape of the blade or actuate trailing edge flaps.

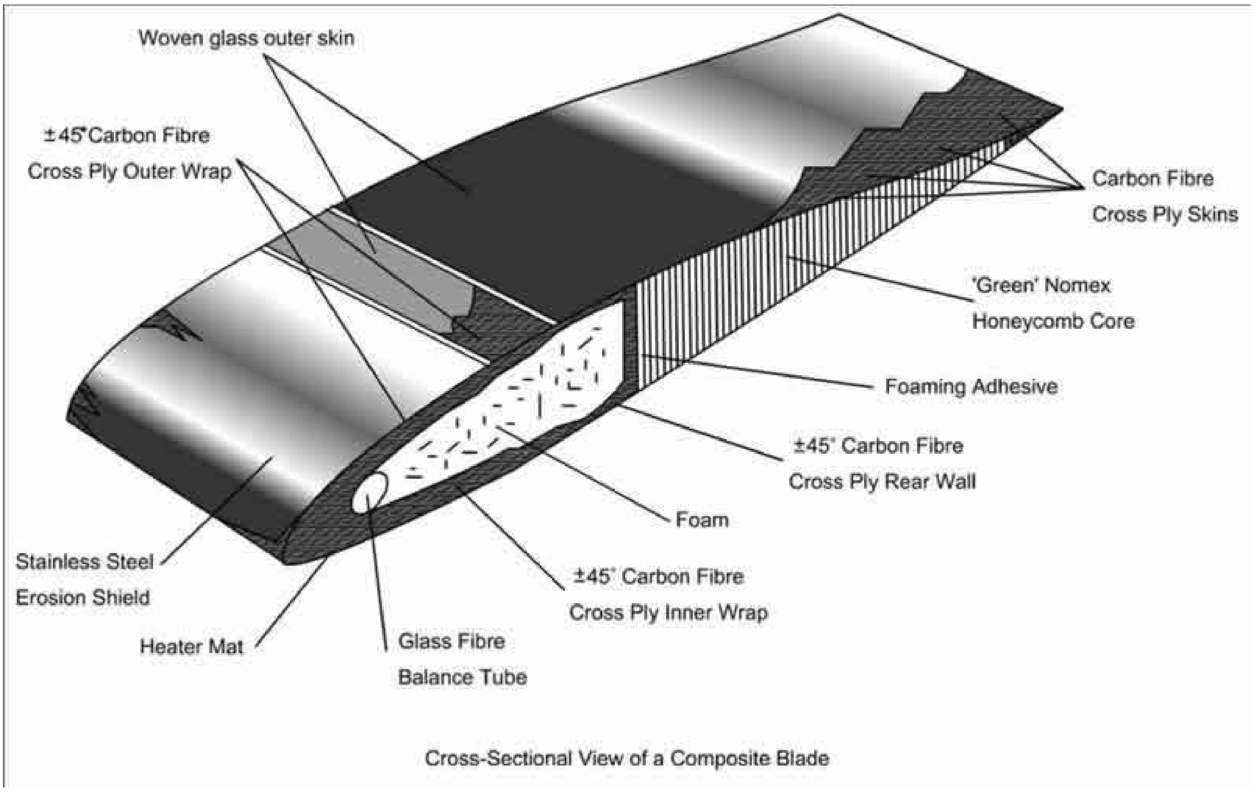


Figure 1: A simple helicopter blade profile

Source: http://classroom.materials.ac.uk/caseRoto.php

The helicopter blade also illustrates a few other attributes of advanced composite products in general:

- It is designed to operate in a very demanding environment, including exposure to dust, weather conditions, even bird strikes
- The properties of the polymer composite part lie outside the boundaries of products made with traditional materials
- It is built using high performance materials
- If it fails injuries and even death will follow
- It needs to combine the lowest possible weight with the highest possible strength
- Every blade needs to conform to the same specification
- Failure of the part also leads to reputational and liability risk, not only of the specific manufacturer but also of the advanced composite materials in general.

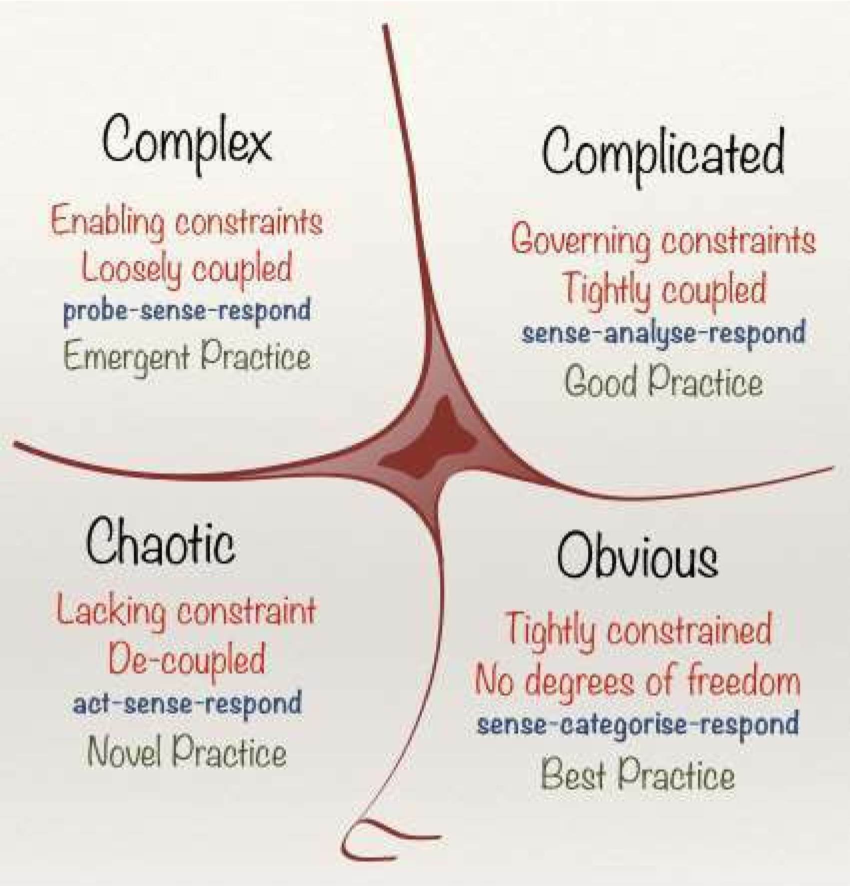
Figure 2: An Oryx helicopter in operation

Screen clipping taken: 2016-11-03 19:17 http://www.denelaerostructures.com/customers/past-customers/agustawestland

Advanced composites also need an advanced manufacturing mindset. The advanced engineering mindset requires interdisciplinary thinking. It also requires dealing with complex variables and interrelationships. The Cynefin model may help distinguish the mind set required in advanced composites from the mindset required in FRP.

Cynefin model

Cynefin, pronounced ku-nev-in, is a Welsh word that signifies the multiple factors in our environment and our experience that influence us in ways we can never understand (Snowden and Boone 2007:unpaginated).



Source: https://en.wikipedia.org/wiki/Cynefin_Framework#/media/File:Cynefin_as_of_1st_June_2014.png

In the Cynefin model, problems are categorised into 5 domains. The descriptions below are compiled from a variety of sources as well as my notes of a presentation by Professor Snowden at the Tshwane University of Technology on 25 August 2015 correlated with various resources on the WWW.

1. Obvious[2] is the domain of **best practice**.

- **Characteristics:** Problems are well understood and solutions are evident. The relationship between cause and effect is clear. Solving problems requires minimal expertise. Many of the problems are addressed by standard operating procedures, FAQs, problem-solving guides and help desks.
- **Approach:** Since the problems here are well known, the correct approach is to sense the situation, categorise it and apply standardised solutions.

2. Complicated is the domain of **good practices**.

[2] *Formerly known as "simple" but changed to "obvious" in the 2014 revision.*

- **Characteristics:** Assessing the situation requires expert knowledge to determine the appropriate course of action or will require some sort of rigorous investigation.
- **Approach:** Sense the problem and analyse it. Then apply expert knowledge to assess the situation and determine a course of action. The plan of action could take the form of the classic problem-solving PDCA Deming cycle of Plan, Do, Check, Act or in other words plan, test, evaluate, implement.

3. **Complex** is the domain of **emergent solutions**.

- **Characteristics:** You don’t even know the right questions to ask. Even beginning to understand the problem requires experimentation. The final solution is only apparent once discovered. In retrospect it seems obvious, but it was not apparent at the outset. No matter how much time you spend in analysis, it is not possible to identify the risks or accurately predict the solution or effort required to solve the problem.
- **Approach:** Develop and experiment to gather more knowledge. Execute and evaluate. As you gather more knowledge, determine your next steps, amplifying that which works and dampening that which fails. Your goal is to move the problem into the *complicated* domain.

4. **Chaotic** is the domain of **novel solutions**.

- **Characteristics:** Problems in this domain are overwhelming and unexpected.
- **Approach:** The first priority is containment. Your initial solution may not be the best, but once you have a measure of control, assess the situation and determine next steps. This takes you back into the *complex* domain.

5. Disorder is the space **in the middle.**

- **Characteristics:** If you are uncertain and don’t know where you are, you’re in “Disorder”.
- **Approach:** Gather more information on what you know or identify what you don’t know. Get enough information to move to a more defined domain.

The boundaries of the domains are not hard edged and problems can lie across the boundaries.

If we analyse the problems that the FRP industry has to solve, FRP products require the solving of problems that lie in the *obvious* domain or on the borderline between the *obvious* and the *complicated* domains. The manufacturing processes have been largely sorted out over the last 50 years or so. Best practices guide the manufacturing process and novel solutions are only required from time to time. That is not to say that problems which could fall into the *complex* domain never arise.

If we analyse the problems that the advanced composites industry is trying to solve, they stretch from the *complicated* to the *complex* domains.

- Designs are often novel
- Designs are always trying to trade off weight and performance, i.e. reduce weight but maintain strength
- Developing solutions often needs extensive testing and experimentation
- The wide range of resins, reinforcements (how they are put together), core materials and manufacturing processes can create complex sets of choices and design options
- There is still much active research occurring in the industry as well as in academic and research facilities
- Training needs are multi-faceted and varied.

Conclusion

The chapter has summarised the various types of polymer composite industries and summarised in a little more detail the advanced composites industry. It has also used the Cynefin model to categorise the types of problem the industry is trying to solve and the kind of thinking processes and practices that are required.

The next chapter will profile the South African advanced composites industry.

Chapter 2 – Brief Profile of the Advanced Composites Industry

This chapter briefly describes the advanced composites industry in South Africa. The figures are approximate and are based on a survey done in 2014 by Dr Kjelt van Rijswijk.

Suppliers

There are approximately 31 suppliers. They supply a diverse range of goods and services to the industry. These include polymers, fibre reinforcements, prepregs, core materials, adhesives, paints, consumables, casting materials, and processing and test equipment design and related software. As discussed later, suppliers are also important in terms of technology transfer, knowledge and skills development. Their own expertise, combined with their access to their overseas principals, is an important factor for keeping the advanced composites industry up-to-date.

Industrial and built environment sector

This sector comprises approximately 40 companies ranging from small to large companies. They broadly fit into the FRP sector although some products can be classified as advanced composites.

Typical products include tanks, pressure vessels, piping, walkways, gratings, drains, cable trays and roof sheets. The sector also manufactures specialised casings, housings and covers as well as drill rig super structures, mining support systems, and rail and port infrastructure.

Corrosion resistance is one of the key drivers in this sector.

Land-based transport

This sector supplies components to road and rail-based transport. For road transport this includes components for motor vehicles, trucks, trailers, dumpsters, canopies, caravans, motor homes, and electric and solar vehicles. For rail-based transport this includes components such as nose cones, pantographs, train seats and interiors as well as bogies.

Key drivers in this sector are mass reduction.

Aerospace and defence sector

This sector truly lies squarely in the field of advanced composites. This sector comprises some 40 companies, including service providers, and manufactures aircraft components (both interior and exterior for local application as well as for export) and small aircraft including gliders and unmanned aerial vehicles (drones), missile casings, helicopter blades, radomes, sensor fairings and casings, as well as satellite components. The sector also includes aircraft repairs. Export customers include Airbus and Boeing.

Drivers in this sector are low weight and high strength vs weight characteristics as well as the ability to withstand exposure to extreme conditions. The sector is also supported by a strong research community. Unlike other sectors it has a representative forum, the Aerospace and Defence Composite Forum, which in turn reports into the Joint Aerospace Steering Committee under the Department of Trade and Industry (the dti).

Ballistics sector

This sector consists of 10 companies making bullet proof vests, helmets, bomb disposal gear, bomb blankets and components for military vehicles, VIP protection, cash-in-transit vehicles and helicopter seats.

This sector uses high performance fibres such as aramid and Ultra High Molecular Weight Polyethylene for their impact resistant properties as well as high performance resins such as polyimide. Products can be manufactured from just the fibres as well.

Industry associations

Currently there is no industry association for the polymer composites industry in general, let alone one for advanced composites. One of the difficulties, according to Dr Kejlt can Rijswijk, is that the composites industry is cross sectoral and that this is the main reason the Polymer Composites Institute of South Africa dissolved. The industry has had a history of such associations failing since the 1980s.

The Mandela Bay Composites Cluster (MBCC) has been established to address the complex net of interested parties. These include sector desks at various national government departments, provincial and local government, material suppliers, education and research facilities and manufacturers. Such a cluster removes the need for entities to belong to or interface with multiple associations. The role of the MBCC is multifaceted and includes skills and technology development. (van Rijswijk, 2016)

Conclusion

The range of products in size, shape and performance gives in indication of the bespoke nature of the advanced composites industry. The implications are that the design and manufacturing skills vary greatly across the sector with a great deal of design, process and product variation.

Chapter 3 – Study Methodology

Proposed methodology for mapping skills

In previous research projects for the Plastics Chamber we pioneered, tested and validated a skills mapping process based on value chains for the plastics, rubber and composite industries, see the following MerSETA reports:

- *Plastics Chamber Regional Workshops: Workshop Report, April to June 2011*
- *Plastics Chamber Research Project Phase II* - Final Report 2013, the PowerPoint presentation *Plastics and rubber industry value chain maps* and the spreadsheet *Guide to Plastics Rubber Jobs and Occupations*

The value-chain approach consisted of the following elements:

1. Compiling a value chain of the manufacturing processes
2. Linking a job or jobs to each node of the value chain
3. Compiling a skills profile of each job, including
    a. products or service delivered
    b. tasks
    c. core skills
    d. foundational knowledge
4. Based on the information collected, linking the job to an occupation on the OFO

Based on this approach the following process was proposed:

- Determine the scope of the mapping process, which manufacturing processes would be covered and how they would be clustered; which of the other value chains are relevant and what the scope of the value chains should cover
- Collect the relevant information from the industry in terms of the process, the related, the skills requirements and current education and training programmes
- Review and validate the *Map 08* to include all low volume composite processes.
- Adapt *Map 06 – Plastics Volume Conversion* to develop a new map or maps which reflect high volume or advanced technical composites industry processes.
- Adapt the job descriptors from the Phase II Chamber research *Guide to Plastics and Rubber Jobs and Occupations* for the all identified jobs in the composites industry, including links to the OFO

- Map these skills profiles to existing training programmes and qualifications
- Conduct a desktop scan of international qualifications and training programmes for composites in 4 selected countries or regions
- Based on the mapping process identify potential qualifications
- Validate the findings with industry representatives
- Present the findings to the MerSETA, CSIR and key industry representatives.

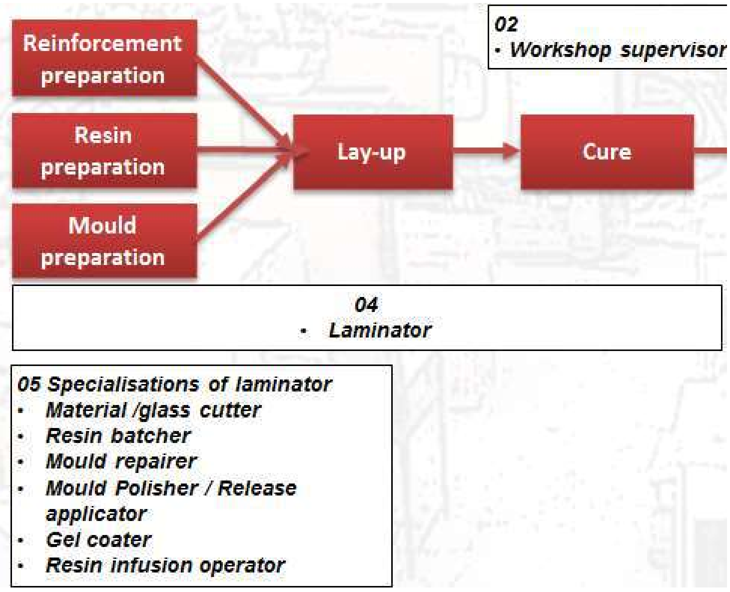
Chapter 4 – Value Chains and Skill Analysis

Introduction

During the Plastics Chamber Research projects Phases I, II, III we used the concept of value chains to evaluate the nature of skills required by the industry.

The purpose of the value-chain approach is to establish each step or node in the value chain. Generally there will a job or jobs associated with each node or value-adding step. Presenting the information in this way also clarifies the purpose of the jobs and assists with identifying alternative job titles and specialisations associated with each job. The value chains were then used to gather information from companies participating in workshops whose purpose was to gather information on skills needs.

In Phase 1 of the research this example from the polymer composites value chain was given to illustrate the above points.



In some companies the laminator performs a range of tasks from reinforcement preparation to de-moulding. In other, usually larger companies, specialists perform aspects of the laminator's tasks and the laminator focuses solely on the application of resin and reinforcement. In still other companies the application of resin is an automated task and only requires an operator to control the equipment.

The resin infusion operator may remain a specialisation for a particular type of product or it may indicate a trend in the way in which this work will be done in the future.

In total 11 value chains were identified:

1. Receiving, dispatch, logistics
2. Mould and tooling manufacture, repair and maintenance

3. Printing, decorating, labelling
4. Quality management
5. Polymer compounding
6. Thermoplastic conversion (volume production, longer runs)
7. Industrial rubber conversion
8. Polymer composites (GRP, FRP, advanced composites)
9. Thermoplastic fabrication
10. Installation, repair and maintenance
11. Recycling

Chains 1 – 4 were generic for most industries, while 5 – 11 were for specific manufacturing processes.

Subsequently jobs identified in the value chains were linked to the list of occupations contained in the Organising Framework for Occupations. For each of the jobs information was collected on the key tasks and the skill requirements.

In Phase 2 of the Plastics Chamber research project the information collected through the value chains was used to structure a survey to gather data on the employees and related information for the jobs identified in each value chain. This proved to be a more successful way of collecting employee data than the method used to collect data in Workplace Skills Plans.

The intention for this study was to use a similar approach to unpack the job and skill requirements for the advanced composites industry.

General value chains

This study does not include the following plastics industry value chains:

1. Receiving, dispatch, logistics
2. Printing, decorating, labelling
3. Quality management
4. Polymer compounding
5. Thermoplastic conversion (volume production, longer runs)
6. Industrial rubber conversion
7. Thermoplastic fabrication
8. Installation, repair and maintenance
9. Recycling

They either are not relevant or they are generic and were dealt with previously.

The mould and tooling manufacture repair and maintenance value chain was expanded to include design. The polymer composites (GRP, FRP, and advanced composites), value chain and the discussions have been more focused on the advanced manufacturing processes.

We begin with a broad overview of the overall, high level value chain.

Overall manufacturing value chain

The first map describes an overall manufacturing value chain. The marketing component has been included to indicate how these inputs act as drivers for the rest of the value chain as well as trying to depict the full life-cycle.

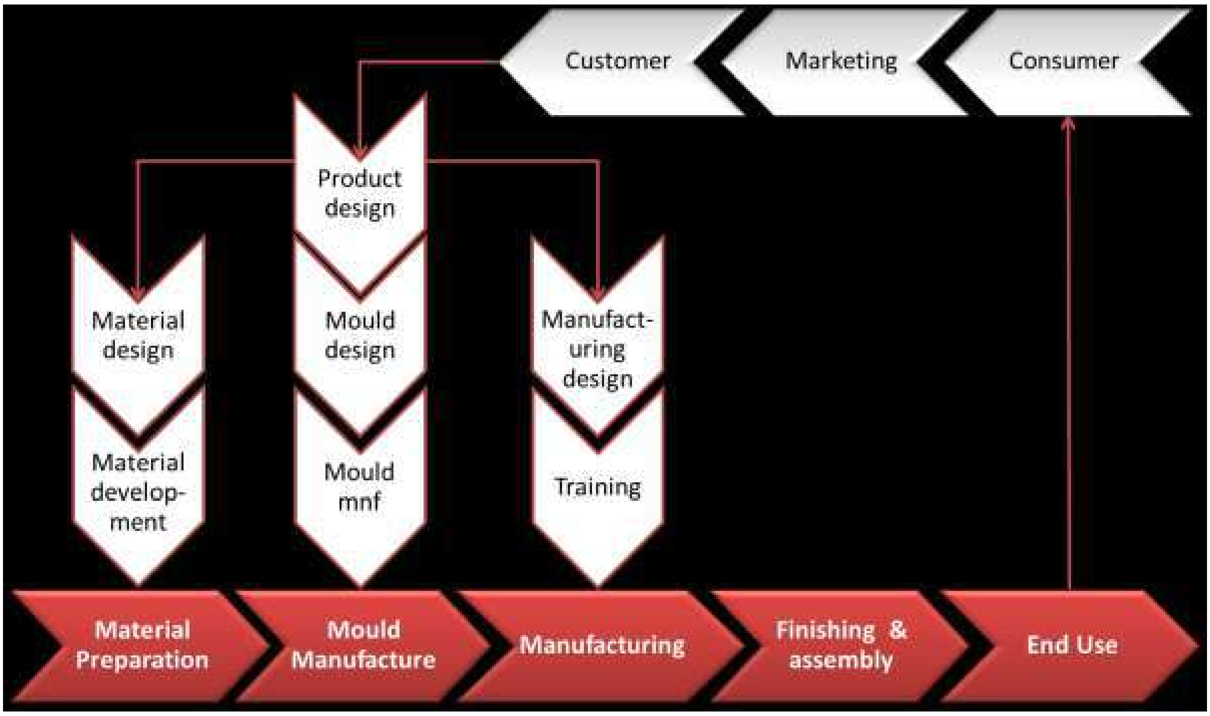


Figure 3: Map 1 - Influence of the market on the advanced composite manufacturing process

The impetus to developing products comes from the market. In some markets the consumers and marketing departments do not play a significant role, e.g. the military. But there will still be trends to address specific requirements.

What this value chain also shows is that there is a significant upfront effort required prior to the manufacturing process. This effort is described in more detail in the next map.

The design, mould manufacturing and preparation value chain

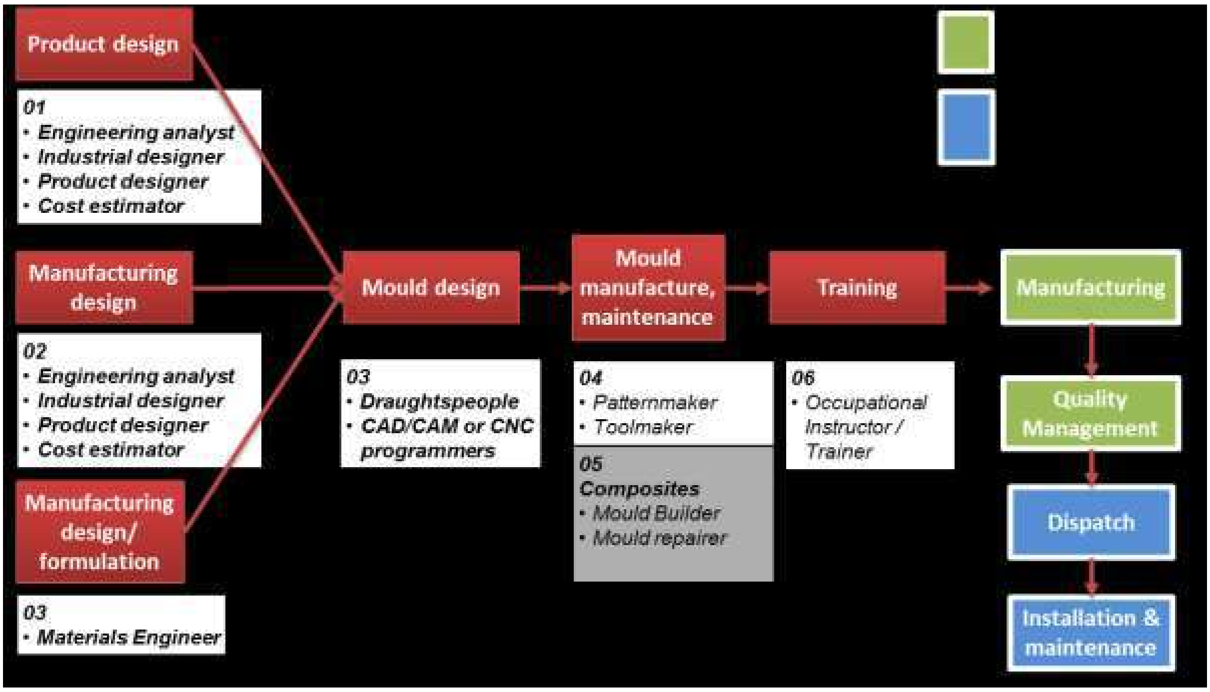


Figure 4: Map 2 – Design, mould manufacture and preparation

This value chain unpacks the previous figure. Two issues emerge:

- Breaking the design process up in this way does not reflect the current reality
- The training process that occurs prior to the manufacturing step.

The design process

What is different in this type of process is the complex manufacturing design process. This step entails:

- a detailed breakdown and selection of the components which will make up the final composite product
- the placement of those components
- the orientation of the various fibre reinforcements
- the achievement of the required mechanical and impact strength with the minimum weight
- the choice of resin or prepreg or the formulation of a resin for the particular application
- the manufacturing process itself
- costing the manufacturing process
- the testing protocols.

Allocating job titles to nodes 1, 2 and 3 creates an artificial distinction. These activities are most likely performed by a single person or multidisciplinary team. The complexity of the design process will be directly proportional to the criticality of the part. Fairly standard components such as brackets will require less expertise, while complex, multi-functional parts will require considerable greater expertise, including experimentation, prototyping and testing as outlined in the previous chapter. The testing process may involve testing to the standard of the relevant international certifying body, or other relevant standard.

Very little of this design work is covered in text books. It is more a product of experience and knowledge of past and current research. The more critical the final composite product is, the more likely it is that the suppliers of the various components will also be drawn into the design process.

This multi-faceted approach to manufacturing a product accords well with the approach called concurrent engineering where all relevant disciplines are brought together into a single design process.

The basic premise for concurrent engineering revolves around two concepts. The first is the idea that all elements of a product's life-cycle, from functionality, producibility, assembly, testability, maintenance issues, environmental impact and finally disposal and recycling, should be taken into careful consideration in the early design phases [3]. The second concept is that the preceding design activities should all be occurring at the same time, or concurrently. The overall goal being that the concurrent nature of these processes significantly increases productivity and product quality, aspects that are obviously important in today's fast-paced market [4]. This philosophy is key to the success of concurrent engineering because it allows for errors and redesigns to be discovered early in the design process when the project is still in a more abstract and possibly digital realm. By locating and fixing these issues early, the design team can avoid what often become costly errors as the project moves to more complicated computational models and eventually into the physical realm [5].

(Retrieved on 2016-11-04 from https://en.wikibooks.org/wiki/Concurrent_Engineering/Introduction)

Based on the above the value chain can be revised to look as follows:

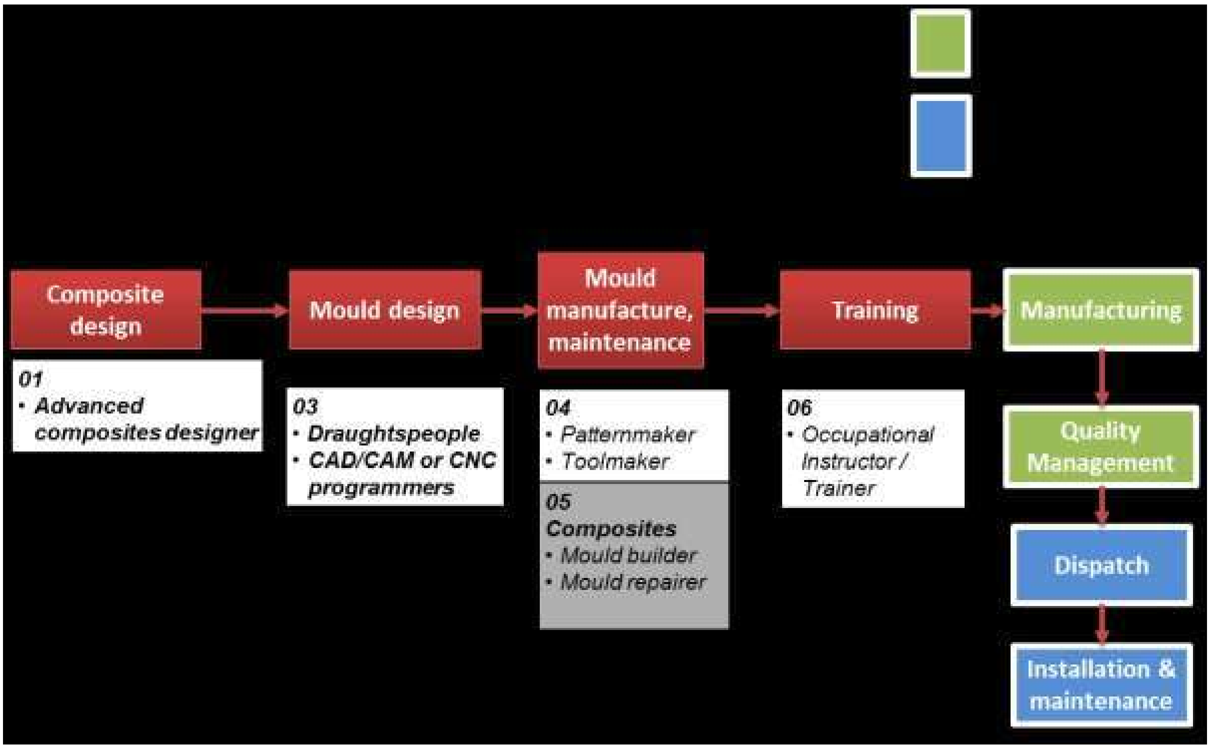


Figure 5: Map 2a - A simplified view of the design, mould manufacture and preparation

Currently "advanced composites designer" is not a recognised occupation. An alternative title could be "composites engineer" which appears to an emerging occupation. As discussed above it could also be a composites team rather than an individual. Internationally these terms have also not found any recognition in occupational classifications systems. The closest matches are Materials Engineer in the USA (retrieved on 2016-12-01 from http://www.onetonline.org/link/summary/17-2131.00) or Australia and New Zealand (retrieved on 2016-12-01 from https://goo.gl/fTQhCY)

This discussion also indicates that while the value chain analysis process is valid, the notion that a job or an occupation can be linked to a node in the chain is, in complex value-adding activities, an over simplification.

However, one can also conclude that because there are no advanced composite specific occupations, all entrants to the advanced composites industry will have to acquire composite knowledge and skills in order to perform effectively.

The preparation process

A surprising element emerged during some of the informal discussions relating to the value chains. Because of the nature of the advanced composites industry, the composites factory worker (see Map 3 below) and perhaps also, the quality inspector and laboratory technician (see Map 2 below) need product- and manufacturing-specific training. The purpose of this is twofold:

1. as part of the overall quality assurance programme
2. as part of certification processes.

Customers may require various forms of certification for safety critical items. This is especially true of customers in assembly industries such as aerospace, aircraft, transport, defence etc. as well as local SANS standards for specific products.

The key role of certification in exports will be discussed later.

Occupational Instructor/Trainer has been linked to that node. This could be a formal position but is more likely to fall to the design team or manufacturing supervisors.

Advanced Composite Manufacturing Value Chain

The manufacturing process is essentially the same as many plastics and fibre-reinforced plastics manufacturing processes.

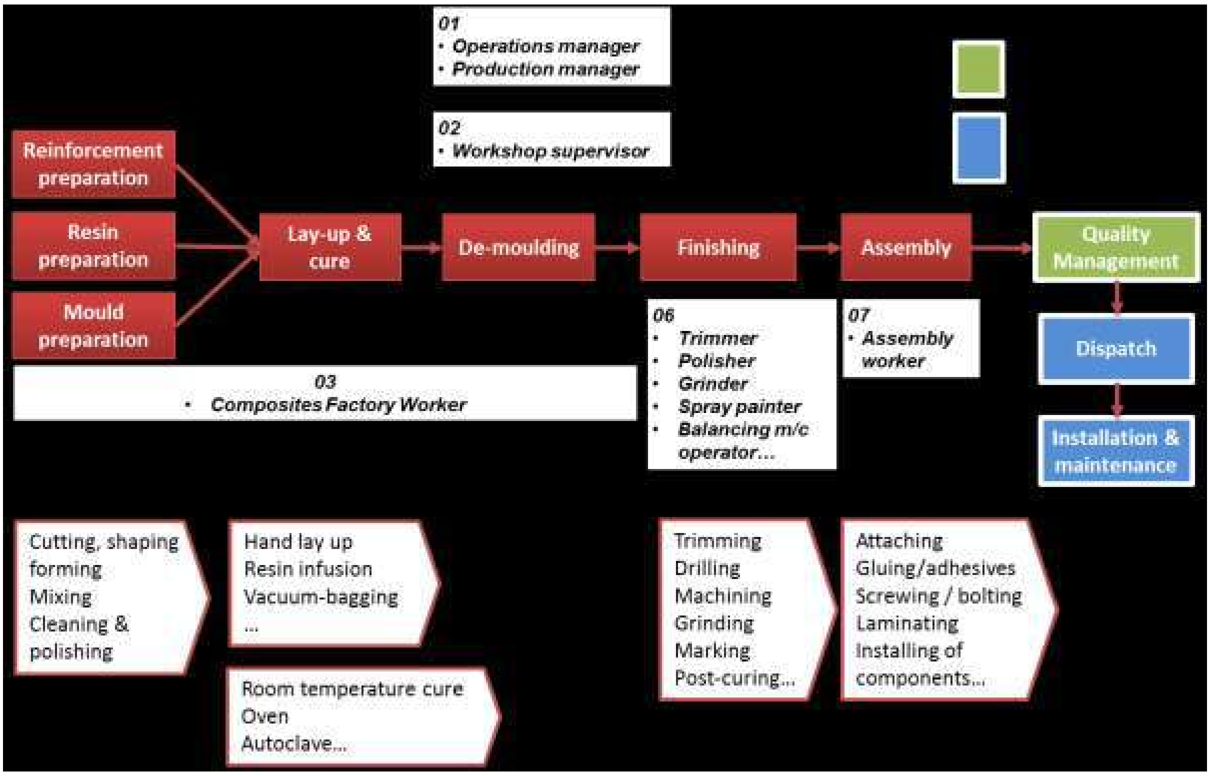


Figure 6: Map 3 - Advanced Composite Manufacturing Value Chain

For the sake of brevity the movement of the materials from the store has been left out.

There are several variations of the advanced composite manufacturing process. These include:

- Wet layup
- Hand layup and vacuum bagging
- Hand layup and resin injection moulding
- Spray-up processes (hand-operated and automated systems)
- Resin infusion
- Resin transfer moulding, with or without vacuum

Composites Factory Workers would be performing slightly different activities for each of the manufacturing processes and the activities would vary with the type and nature of the product, the configuration of the core and reinforcement materials and the curing process. Training such workers to do their job will thus be highly specific as discussed in the design, mould manufacture and preparation value chain above.

Currently in most cases the activities comprise fairly exacting cutting, shaping and placement of materials, some careful use of tools, and the operation of simple machinery or equipment.

New entrants from industrial fibre-reinforced manufacturing processes will have a slight advantage over new workers, whether unemployed or coming from other industry. But the training will be highly process and product specific.

The Quality Management Value Chain

The quality management value chain is slightly different to the rest of the plastics manufacturing processes. There is a tight link between the design function, the laboratory and indirectly the quality inspector.

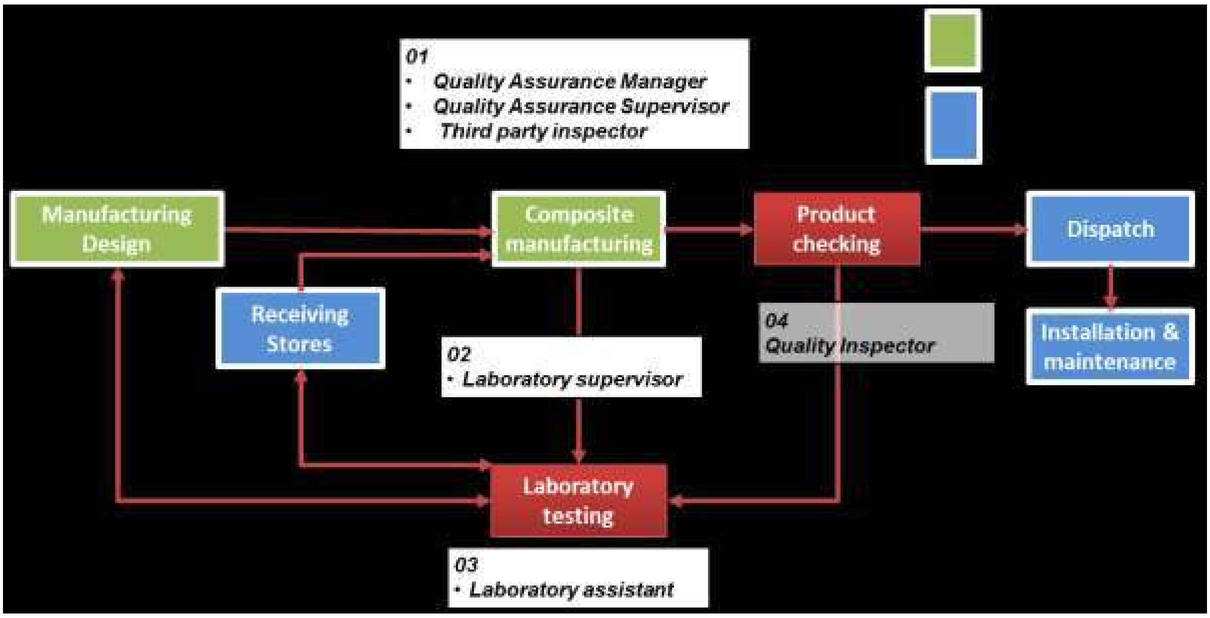


Figure 7: Map 4 - The Quality Management Value Chain showing the tight links to the design function

This situation arises because, as discussed previously, the industry is operating in the Cynefin domains of *complicated* and *complex*. In these domains solutions are not always obvious and may need analysis or experimentation to find solutions.

Negative test results are indicators of a problem which could start with the actual design. In this type of manufacturing any changes made to the materials or the manufacturing process would also have to be approved by the manufacturing design function.

The arrow between the two, the Design Function and the Laboratory, is also depicted as double-headed. This indicates that the design function would also be monitoring test results actively.

Again, one can also conclude that because there are no composite specific occupations, all entrants to the advanced composites industry will have to acquire composite knowledge and skills in order to perform effectively.

The last value chain describes the actual manufacturing process.

Conclusion

The value chain analysis demonstrates that the manufacturing design function is central to the whole manufacturing value chain. The design function not only creates the manufacturing process; it will also be intimately involved in the quality management of the manufacturing process and problem solving.

The characterisation of the advanced composites in the Cynefin framework as lying between the *complicated* and the *complex* domains helps us understand how these value chains are different from the value chains for industrial plastics manufacturing processes.

Finally, the skills and knowledge required by staff in such establishments are fairly specific to the production processes and types of products produced.

Chapter 5 – Current Training Related to Composites

Introduction

This chapter outlines the qualifications and training opportunities available to the advanced composites industry in South Africa. It also briefly discusses examples of some international approaches to training and qualifications.

Finally it discusses some of the issues involved in developing national qualifications.

Current qualifications

The following table lists currently registered qualifications relating to polymer composites and polymers in general. The information is based on a search of the South African Qualifications Authority qualification database http://allqs.saqa.org.za/index.php

Table 1: List of nationally registered qualifications containing unit standards or modules related to polymer composites and FRP/Advanced composites

	Qual ID	Qualification Type	Title	NQF Level	NQF Sub-Framework	Min Credits	Status	Registration End Date	Quality Assuring Body	Accredited Providers
1.	61233	Designated trade	Vehicle body builder (composite) – metal [1]	n/a	Undefined		Recorded as Trade		QCTO	n/a
2.	96352	Designated trade	Reinforced plastics and composite trades worker [1]	n/a	Undefined		Recorded as Trade		QCTO	n/a
3.	60921	Designated trade	Aircraft composites and structures – Transnet [1]	n/a	Undefined		Recorded as Trade		QCTO	n/a
4.	60944	Designated trade	Plastics and fibreglass worker – Transnet [1]	n/a	Undefined		Recorded as Trade		QCTO	n/a
5.	36154	National Certificate	Polymer Composite Fabrication [2]	2	OQSF	132	Reregistered	2018-06-30	MERSETA	Beekman Super Canopies; Plastics Federation of South Africa [4]
6.	36155	National Certificate	Polymer Composite Fabrication [2]	3	OQSF	130	Reregistered	2018-06-30	MERSETA	Beekman Super Canopies; Plastics Federation of South Africa [4]
7.	36153	Further Education and Training Certificate	Polymer Composite Fabrication [2]	4	OQSF	154	Reregistered	2018-06-30	MERSETA	Beekman Super Canopies; Plastics Federation of South Africa [4]
8.	77003	National Certificate	Yacht and Boat Building [2]	2	OQSF	136	Reregistered	2018-06-30	MERSETA	False Bay Public FET College - Westlake Campus
9.	78863	National Certificate	Yacht and Boat Building [2]	3	OQSF	136	Reregistered	2018-06-30	MERSETA	False Bay Public FET College - Westlake Campus
10.	48861	National Certificate	Aircraft Maintenance and Overhaul [2]	4	OQSF	180	Reregistered	2018-06-30	TETA	None
11.	66489	Further Education and Training Certificate	Foundry Operations	4	OQSF	128	Passed end-date	2015-07-30	MERSETA	n/a

	Qual ID	Qualification Type	Title	NQF Level	NQF Sub-Framework	Min Credits	Status	Registration End Date	Quality Assuring Body	Accredited Providers
12.	50021	Further Education and Training Certificate	Inspection and Assessment (Non-Metallics)	4	OQSF	150	Reregistered	2018-06-30	MERSETA	None
13.	60070	National Certificate	Inspection and Assessment (Non-Metallics)	5	OQSF	138	Reregistered	2018-06-30	MERSETA	None
14.	60072	National Diploma [3]	Inspection and Assessment (Non-Metallics)	5	OQSF	241	Reregistered	2018-06-30	MERSETA	None
15.	94573	Occupational Certificate [5]	Boat Builder and Repairer (Boat Builder)	4	OQSF	360	Reregistered	2018-06-30	QCTO	None
16.	97155	Occupational Certificate [5]	Boat Builder and Repairer (Shipbuilder)	4	OQSF	437	Registered	2018-06-30	QCTO	None
17.	93623	Occupational Certificate [5]	Engineering Patternmaker	4	OQSF	360	Reregistered	2018-06-30	QCTO	None
18.	99559	Occupational Certificate [5]	Wind Turbine Service Technician	5	OQSF	123	In the registration process	2018-06-30	QCTO	n/a
19.	78658	National Diploma [3]	Plastic Technology	6	HEQSF	360	Reregistered	2018-06-30	CHE	Cape Peninsula University of Technology
20.	87137	National Diploma [3]	Polymer Technology	6	HEQSF	360	Reregistered	2018-06-30	CHE	Nelson Mandela Metropolitan University
21.	72628	National Diploma [3]	Polymer Technology	6	HEQSF	360	Reregistered	2018-06-30	CHE	Tshwane University of Technology (TUT)
22.	97106	Diploma [3]	Polymer Technology	6	HEQSF		Registered-data under construction		CHE	Nelson Mandela Metropolitan University
23.	78680	National Higher Diploma [3]	Plastics Design Technology	7	HEQSF	120	Reregistered	2018-06-30	CHE	Cape Peninsula University of Technology

	Qual ID	Qualification Type	Title	NQF Level	NQF Sub-Framework	Min Credits	Status	Registration End Date	Quality Assuring Body	Accredited Providers
24.	72446	Bachelor of Technology [3]	Polymer Technology	7	HEQSF	480	Reregistered	2018-06-30	CHE	Tshwane University of Technology (TUT)
25.	87099	Bachelor of Technology [3]	Polymer Technology	7	HEQSF	480	Reregistered	2018-06-30	CHE	Nelson Mandela Metropolitan University
26.	81913	Master of Science	Polymer Chemistry	9	HEQSF	120	Reregistered	2018-06-30	CHE	University of Limpopo
27.	72360	Doctor of Technology	Polymer Technology	10	HEQSF	240	Reregistered	2018-06-30	CHE	Tshwane University of Technology (TUT)
28.	81911	Doctor of Philosophy	Polymer Chemistry	10	HEQSF	240	Reregistered	2018-06-30	CHE	University of Limpopo

Source: http://allqs.saqa.org.za/search.php?cat=qual – various searches. Information validated on 20 October 2016

Notes

1. These trades will be replaced by the following National Artisan Moderation Body (NAMB) listed trade3: 714209 Reinforced Plastics and Composite Trades Worker.
2. These certificates will also eventually be replaced with trade or trade-related part qualifications.
3. The Diplomas at level 6 and the Bachelors of Technology at level 7 contain modules on composites.
4. Accredited providers: In the interest of simplifying the table, the full details of the providers have been shortened. Beekman Super Canopies as recorded on the SAQA database is Beekman Super Canopies (STIKLAND) (TP). Similarly, Plastics Federation of South Africa has three accredited sites, namely Plastics Federation of South Africa (MAITLAND) (TP), Plastics Federation of South Africa (MIDRAND) (TP) and Plastics Federation of South Africa (WESTMEAD) (TP)
5. These are the new form of trade and occupational qualification. The Boat Builder and Repairer and the Engineering Patternmaker qualifications represent revised trades (See below).

[3] Regulation 691 of 30 August 2012: Listing of occupations as trades for which artisan qualifications are required

Accredited providers of FET qualifications

There are only two accredited providers of polymer composite qualifications in the Further Education and Training band (FET) of the NQF. They are Beekman Super Canopies in Cape Town and Plastics Federation of South Africa, (now Plastics SA) which has training centres in three major centres around the country. One can conclude that there is limited take up of these qualifications.

MERSETA and the Transport Education and Training Authority have learnerships registered against these qualifications. TETA's learnerships are registered as Aircraft Composite Structures Technician learnerships. However, there are no accredited providers, so it does not seem likely that these are active learnerships.

Other tertiary education

Composites also feature in the research and teaching programmes of several universities. These programmes are mostly within the faculties of mechanical engineering. The institutions offering the programmes include the Universities of North West, Pretoria, Stellenbosch and the Witwatersrand, as well as the Durban University of Technology. There is also a Composite Manufacturing Technology Station at the Vaal University of Technology which focuses on the technology transfer, knowledge and skills development.

From Masters level onwards, students in mechanical engineering can and do specialise in advanced composites.

Occupational Certificates

Occupational Certificates represent the new style of work-focused qualifications on the NQF. Instead of unit standards they have a curriculum which describes the learning content and learning activities. These qualifications are registered through the Quality Council for Trades and Occupations (QCTO). QCTO qualifications have to link to the Organising Framework of Occupations (OFO) and consist of a curriculum, external assessment specifications and a qualification document for registration purposes. The curriculum consists of three types of module, knowledge, practical skills (off-the-job) and work experience modules.

Three of the occupational certificates listed in the table (Nºs 15, 16 and 18) contain curriculum components which focus on polymer composites. The fourth, the Engineering Patternmaker (Nº 17 in the table) contains references to resins and the manufacture of resin patterns. This is a reference to FRP. The qualification has also been included because the Engineering Patternmaker is a skill identified in the value chain Map 2 – Design, mould manufacture and preparation, see above, Chapter 4.

The curriculum document linked to the Boat Builder qualification (Nº 15 in the table) contains the following modules:

Knowledge Modules

Basic principles of composite construction, L2, Cr4

Theories of composite construction and repair, L3, Cr6

Theories and principles of advanced composite construction, L4, Cr6

Practical skills modules

Apply basic boat building skills using materials, tools and equipment, L2, Cr4

Measure and mix resin system and prepare mould surface, L2, Cr4

Produce a plug, L3, Cr8

Identify common defects and repair gel coat in boat building, L3, Cr4

Fabricate advanced composite components in boat building, L4, Cr8

Work experience modules

Boat and component part construction processes and procedures using either composites, aluminium, wood or inflatable fabric (or a combination of these materials) in a boat building yard, L4, Cr120 (QCTO, undated-a)

Composites is only one of several options in the work experience module, meaning that not all learners will necessarily be exposed to the composites production environment.

The curriculum for the Ship Builder and Repairer qualification (Nº 16 in the table) only contains a brief overview of composites in the knowledge modules and there is no reference to composites elsewhere in the curriculum (QCTO, undated).

The curriculum for the Wind Turbine Service Technician (Nº 18 in the table) contains the following:

Knowledge topic

> *Inspection principles for servicing and maintenance of rotor blades and composite components of wind turbines, L5, Credits approximately 4*

The topic appears in a larger module "Wind Turbine Technology, NQF Level 5, Credits 26"

Practical skills module

> *Inspect, assess and address composite parts and components, NQF Level 5, Credits 8 (QCTO, undated-c)*

This module covers both the inspection and the repair aspects.

Unit standards

The registered unit standards for polymer composites are listed in the following table. They mostly apply to FRP but could be used for advanced composites. The list does not contain any generic unit standards. The selection of unit standards was limited to those which refer directly to polymer composites. There are a wide range of unit standards for general and associated activities such as inspection, testing and quality management in general.

Table 2: List of unit standards related to polymer composites

U Std ID	Unit Standard Title	NQF Level	Originator	Credits	Status	Accredited Providers
123599	Apply the fundamental methods of composite, wood and metal small craft construction	3	SGB Manufacturing and Assembly Processes	10	Reregistered	False Bay Public FET College - Westlake Campus
115274	Assemble aeronautical metal components and/or composites by bonding	4	SGB Aircraft Maintenance and Overhaul	10	Reregistered	Beekman Super Canopies Plastics Federation of South Africa
376560	Construct and repair composite marine components	3	SGB Manufacturing and Assembly Processes	15	Reregistered	False Bay Public FET College - Westlake Campus
376582	Demonstrate an understanding of structural composites	4	SGB Manufacturing and Assembly Processes	20	Reregistered	Beekman Super Canopies False Bay Public FET College - Westlake Campus Plastics Federation of South Africa
110285	Demould a polymer composite product	2	SGB Plastics Manufacturing	5	Reregistered	Beekman Super Canopies False Bay Public FET College - Westlake Campus Plastics Federation of South Africa
110281	Fabricate a polymer composite product	2	SGB Plastics Manufacturing	9	Reregistered	Beekman Super Canopies Plastics Federation of South Africa
110283	Fabricate specialised polymer composite parts and complex assemblies	4	SGB Plastics Manufacturing	28	Reregistered	Beekman Super Canopies Plastics Federation of South Africa
110289	Identify and work with material as required for polymer composite fabrication	2	SGB Plastics Manufacturing	8	Reregistered	Beekman Super Canopies False Bay Public FET College - Westlake Campus Plastics Federation of South Africa
110276	Maintain the quality of fabricated polymer composite products	4	SGB Plastics Manufacturing	24	Reregistered	Beekman Super Canopies Plastics Federation of South Africa
110278	Prepare damaged polymer composite product for repairs	2	SGB Plastics Manufacturing	6	Reregistered	Beekman Super Canopies False Bay Public FET College - Westlake Campus Plastics Federation of South Africa
110279	Prepare mould for polymer composite fabrication	2	SGB Plastics Manufacturing	8	Reregistered	Beekman Super Canopies False Bay Public FET College - Westlake Campus Plastics Federation of South Africa
110280	Produce complex polymer composite products	3	SGB Plastics Manufacturing	28	Reregistered	Beekman Super Canopies False Bay Public FET College - Westlake Campus Plastics Federation of South Africa

Notes

Accredited providers: In the interest of simplifying the table, the full details of the providers have been shortened. Beekman Super Canopies as recorded on the SAQA database is Beekman Super Canopies (STIKLAND) (TP). Similarly, Plastics Federation of South Africa has three accredited sites, namely Plastics Federation of South Africa (MAITLAND) (TP), Plastics Federation of South Africa (MIDRAND) (TP) and Plastics Federation of South Africa (WESTMEAD) (TP)

It is again worth noting the small number of accredited providers. One of the contributing factors to this situation is that it is difficult for providers to obtain accreditation if they do not provide the training at their own fixed premises. If they run courses at their customers' sites they need to apply for accreditation for each site at which they do the training.

It is also worth noting that the unit standards are fairly generic but at the same time, if one looks at the content, they really reflect the predominant FRP processes of hand lamination.

In other words advanced composites manufacturing techniques are not adequately covered by the unit standards.

Other training options

In the absence of national standards for advanced composites training there are providers of specialised and non-formal and informal training.

Specialised training

There is one specialised training provider for the range of polymer composite training. This is the Composites Training Academy, which provides training at various NQF levels for polymer fabrication, yacht and boat building as well as specialised short courses in processing and repair for polyester and epoxy resins, and resin infusion, as well as courses for the production and repair of specific products such as tooling, wind turbine blades and radio telescope dishes.

The Composites Training Academy also offers to facilitate recognition of prior learning processes against national qualifications in polymer composite fabrication and yacht and boat building.

What is also evident from the academy's course offerings is that it is ahead of the qualification development processes. They are developing courses as the demand arises, but before there is something against which they obtain accreditation. This is typical of a industry where technology evolves quickly.

Other specialised training providers include Denel Training Academy which offers an advanced polymer composites repair course and Aerosud, which supplies components to aircraft manufacturers. Aerosud has recently developed a TETA-approved apprenticeship specialising in composite aircraft structures alongside the existing trade for the aircraft structures worker.

Universities and research facilities also offer short courses on specialised aspects related to composites and there is a proposal for the development of short courses for design work (van Rijswijk, 2015). There is, however, no coherent programme of courses at this level.

Supplier training

A feature of the polymer composites industry is that material and equipment suppliers provide a range of training resources to customers, new entrants to the industry and the general public (the hobbyist). These include:

- introductory guides
- videos
- online courses
- guidelines
- short courses of varying duration
- technical guides
- standard workshop practice guidelines

Apart from these resources suppliers also assist with advice, consultation and technical services. They form a key role in technology transfer and technology partnerships.

Conclusion

Specialised, non-formal and informal training fulfils an important requirement for the advanced composites industry.

Composites training internationally

The purpose of this section is to provide a brief overview of what is happening internationally. It is not meant to be an exhaustive guide.

The pattern is very similar to the training solutions evident in South Africa.

Composites Technician

Several countries (Australia, Canada, the United Kingdom and the United States of America) have trades or extensive training programmes for composites. In general, the industries in those countries are bigger and more developed than the local industry.

The primary focus of these apprentice-style programmes still seems to be mainstream industrial FRP processes, but manufacturing processes linked to advanced composites such as resin infusion are also reflected.

Study of Technician training in the UK

Paul Lewis conducted a study of technician training in the UK composites industry. Technicians were defined as falling either into the class of skilled craft worker (artisan) or of associate professional (Lewis, 2013:1).

He concluded that most laminators (fabrication workers) were semi-skilled at Level 2 and are not classified as technicians (Ibid: 2). Where more automated methods of fabrication were used, e.g. filament winding and automated fibre placement or tape laying, the skill level was pegged at Level 3. This work could be classified as technician level.

But the key technicians operated as a “team leader or supervisor, machinist, non-destructive testing technician, mechanical testing technician, maintenance technician, aircraft fitter, air craft mechanic, draughtsman or junior design engineer, engineering, quality engineer, and category ‘B’ licensed aircraft engineer in the case of ‘associate professions/technical roles’” (Ibid: 2).

Most firms manufacturing composite components relied on the semi-skilled composite fabricators. The aerospace industry employed the highest number of technicians “(i) to machine, test, and quality assure composite components, even when the parts in question are made by semi-skilled laminators… or (ii) maintain, repair and overhaul aircraft” (Ibid: 2).

Employers relied on in-house training, coupled with “external upgrade training” in order to train the semi-skilled composite fabricators. The training tends to focus on the specific job requirements, (Ibid: 3). Technician level training largely consisted of additional composite modules linked to traditional engineering trades or engineering qualifications at Level 4. (Ibid: 3f).

All of the above indicates that the "composite skills" are additional to the skills of a primary occupation.

Where organisations were increasingly substituting metal components with composite ones they were retraining their workforce, sometimes with "extensive in-house training programmes" (Ibid: 5). One of the challenges faced in training or retraining the workforce was that there were few local institutions, such as colleges, to offer modules related to composite manufacturing. Where such training was offered, it was often deficient because the colleges lacked the "facilities and the instructors required to teach best practice techniques" (Ibid: 5). Larger employers could influence and assist their local colleges to develop relevant programmes or were conducting their own in-house training. For smaller firms these were not affordable options. (Ibid: 5).

Lewis concluded that, "There appears to be a clear need to expand provision for high-quality training in working with composite materials." (Ibid: 5).

The recommendations Lewis makes are for policy makers and tend to be very general, e.g. "helping to disseminate information", "sharpening the incentives" and exploring various options (Ibid: 5 and 54).

The one more specific recommendation he makes relates to National Occupational Standards. These standards are used as a reference point for training programmes and as a framework for career development (Ibid: 5). While there are some problems associated with the use of these standards (Ibid: 48f) they do offer a starting point (see below, page 51).

The report demonstrates some clear parallels to the situation in South Africa. Even in the UK where the industry is much larger employers can't rely on the education and training system to deliver the type of skills that they need. They need to rely on in-house courses and some external-upgrade courses to develop the skills they require.

Short Courses

There are also a plethora of short courses related to composites in the above countries. They range from introductory to highly specialised courses. The duration ranges from one day to a month.

Certification courses

The United Kingdom and the United States also offer certification programmes. The UK has a Composites Assured Practitioner Scheme. The purpose of the scheme is to raise the level of skills and to provide assurance to customers that the manufacturers comply with audited quality standards.

> *Each individual is assessed against the competencies agreed for your business and marked as performing at a skill level against each relevant entry. The individual will gain a competency passport which is a record of their competency level across a range of skills assessed. Each passport is valid for 3 years and can be renewed at that time or before then if required – a renewal fee will apply.* (Retrieved on 2016-10-21 from https://compositesuk.co.uk/industry-support/composites-assured-practitioner-cap-scheme)

The scheme is managed and promoted by Composites UK, the trade association for the composites industry.

The American Composites Manufacturers Association (ACMA) runs a Certified Composites Technician programme. The aim of the scheme is to:

> *strengthen industry standards, elevate production performance, upgrade individual levels of knowledge and skill and offer public recognition to those who demonstrate a prescribed level of expertise in a specific composites specialization.* (Retrieved on 2016-10-10 from http://www.acmanet.org/cct/)
>
> *CCT designations are available in the following focus areas:*
>
> *Cast Polymer*
>
> *Compression Molding*

Corrosion

Instructor

Light Resin Transfer Molding(Ibid)

Open Molding

Vacuum Infusion Process

Wind Blade Repair

The difference between the two certification schemes is that the UK scheme operates at company as well as the individual level, while the USA programme is essentially focused on individuals.

In Germany the Fraunhofer Academy offers widely-recognised certification for specific aspects of the advanced composites. The certification is based on the attendance of courses ranging from 1 to 4 weeks. The certifications include:

Fiber reinforced plastic specialist

Fiber reinforced plastic remanufacturer (repair)

Fiber reinforced plastic fabricator

Fiber Composite Engineer

(Retrieved on 2016-10-30 from http://www.academy.fraunhofer.de/en/continuing-education/manufacturing-testing-technology/fiber_composite_technology.html)

Fraunhofer also offers a further certification in adhesive bonding.

National Occupational Standards

Sector Skills Councils or standards setting organisations in the UK have developed sets of National Occupational Standards for a variety of industries, including composites. An example is SEMPEO2-44 Producing Composite Mouldings using Pre-Preg Techniques, see Appendix 3. The standard contains the following headings: Overview, Specific Standard Requirements, Performance criteria, Knowledge and understanding, Scope/range related to performance criteria. (Retrieved on 2016-10-30 from http://nos.ukces.org.uk/PublishedNos/SEMPEO244.pdf)

While it is not clear if the standards are linked to certification they do provide the basis for such certification. One of the dangers of using such standards for certification is, however, that the training results in fragmented outcomes related to specific individual tasks. They need to a linked to an overall programme which builds “holistic problem-solving ability required” of skilled, technician-level capability (Lewis, 2013: 48f).

The importance of these certification schemes is increasing. Process qualification is a key requirement in order to export. One aspect of process qualification is that the relevant personnel are also certified as qualified. In South Africa the default position is that certification means a nationally recognised NQF qualification. The examples given demonstrate that this need not be the case.

Conclusion

International training in advanced composites follows a similar pattern to that of South Africa. There are mainstream qualifications and apprentice-style training processes, primarily for the industrial FRP processes. More advanced manufacturing processes such as resin infusion and the use of prepregs are generally covered in specialised courses. The reasons for this could be two-fold:

- The manufacturing processes themselves are still evolving and as they evolve so the knowledge and skill requirements evolve. The terminology related to these processes is also very varied as are the number of process variations – of resin infusion, in particular.
- The numbers of people being trained are still relatively small and in many cases the courses will be add-ons to an existing skill set.

With time these manufacturing processes are likely to become part of the mainstream qualifications.

What South Africa lacks is a programme for certifying practitioners. We will address this point in a later chapter.

Chapter 6 – Qualification Options

This chapter looks at some options for developing qualifications relevant to the advanced composites sector.

The development and implementation of the Occupational Sub-Framework of the NQF has created some new opportunities.

Proposed new trade qualification

NAMB has listed a trade for Reinforced Plastics and Composites Worker against the OFO code 714209. The new Reinforced Plastics and Composites Worker trade would replace the old designated trades and would, more than likely, be primarily focused on FRP. The qualification will probably be developed through the Transport Education and Training Authority (TETA) because the old designated trades for reinforced plastics all fell within the transport sector (see the first four qualifications listed in Table 1, above).

Some of the curriculum may cover advanced composites since these materials are now more common in the aircraft industry and there is a steady increase in their use in other transport applications.

The QCTO has not, as of 31 October 2016, received an application to develop the qualification (Walters: 2016).

TETA has also submitted a new qualification for Aircraft Structures Technician at NQF level 4 to the Quality Council for Trades and Occupations (QCTO) for registration. A small part of this qualification deals with the inspection and repair of composite materials. In addition, other qualifications such as those for aircraft mechanic and vehicle builder also include composites knowledge in the curricula.

Considerations in developing a trade qualification

This section is based on my experiences of developing trade and related occupational qualifications over the last five years.

The QCTO development process is quite intensive and can be time-consuming. The QCTO development process consists of:

1. An occupational analysis
2. Development of a curriculum consisting of
    a. Knowledge modules
    b. Practical skills modules (generally off-the-job)
    c. Work experience
3. Assessment specifications (for the final integrated summative assessment)

This model is also, however, very useful for developing any work-related training process.

NAMB has stipulated that a trade qualification will have a duration of at least three years. In the case of the Reinforced Plastics and Composites Worker the curriculum will be shaped to meet the needs of the transport sector. The primary focus will be on FRP.

The time required for the development and registration of such a qualification, from obtaining consensus to registration, can range from two to four years and the latter is more likely. Our experience to date has been that the transport sector is very intent on ensuring that their interests are met and unwilling to compromise with other stakeholders.

The second experience is that considerable difficulties arise where there are many variations in the trade or occupation. The more homogenous the learning processes are, the easier it is to develop a qualification. The more varied the activities, the more difficult it is to achieve a consensus on the content and scope of the occupation or trade. This is also particularly true of occupations where the technology is evolving quickly. The decisions in this context revolve around how many potential learners would have access to the new technology.

Given the variations in resins, fibre reinforcements and manufacturing processes, it is going to be very difficult to include anything other than the basic FRP processes in the trade qualification. The arguments will often come down to:

- "Why should my fibreglass laminator learn all this fancy stuff?"
- "Including these additional processes will push up the cost of training significantly."

In a similar vein NAMB's approach to the trade test is to pitch it at the lowest common set of skills, i.e. it does not test on-job experience or specialisation. This could mean that apprentices/learner artisans could be tested on one or more of any of the manufacturing techniques they have learned – some of which they will only have learned off-the-job. A case in point is the new trade for Plastics Manufacturing Machine Setter. Apprentices who have specialised in injection moulding could find that their assessment tasks are based on blow moulding or an extrusion process. If advanced manufacturing techniques are included in the curriculum the trade test will most likely not assess those specifically but would probably focus entirely on hand layup processes with glass fibre and polyester resin.

Given the above complexities it should not, however, be forgotten that this trade qualification is the equivalent of the international Composites Technician. While the fabrication skills are important, the real role of the technician is to oversee the manufacturing process as a team leader or supervisor. This person should be capable of overseeing the workflow, managing the quality, resolving problems and training the fabricators.

Part qualifications

One option to tailor learning for the advanced composites industry would be to create part qualifications for various advanced composites manufacturing techniques. In each case the overall process and qualification would be equivalent to a mini-trade.

The QCTO model allows for the development of part qualifications. Part qualifications are combinations of curriculum components for a specific purpose. They need to consist of a minimum of 25 credits (approximately 6 – 7 weeks of learning including work experience). Conceptually part qualifications are similar to skills programmes, except that they include work experience modules.

However, it would still be difficult to cater for all the variation in advanced composite manufacturing processes with this option. This training option is also fairly expensive and requires significant time and effort. Given the relatively small number of potential trainees/learners it is unlikely to be a cost effective option.

From a qualification development and assessment perspective part qualifications create a great deal of complexity. This generally adds to the development time of such qualifications.

Recommendation: I would recommend that we avoid the part qualification option. There are other ways of achieving the foundational training. This is an option that can be considered when the industry has grown sufficiently for the number of learners to reach a sustainable threshold.

Other options

While the trade is one option for developing a qualification, there are also two other options for registering national qualifications.

Other occupations

The OFO also lists an occupation at fabricator level: 714209 – Reinforced Plastics and Composite Trades Worker.

To cater for the variations in the industry this qualification could consist of a series of part qualifications for the major variations of the FRP and advanced composite manufacturing processes.

The advantage of this approach is that the qualifications would be pitched directly at the level of the fabricator and not at a potential technician-level person.

The downside of this approach is very similar to the issues relating to part qualifications discussed above.

Advanced composites as specialisations

In addition to developing the qualification at a trade or fabricator level, the QCTO model also allows for the development of specialisations linked to the particular occupation as separate qualifications, e.g. resin infusion operator or filament winding operator.

While this is possible and has been done in a number of instances the QCTO policy of not allowing a proliferation of qualifications is making it difficult to get approval of such applications. The advanced composites industry would have to compile a very convincing motivation for the application to succeed. At present it seems that only if large numbers of learners are guaranteed will the QCTO agree to the development of specialisations. Where there are a range of specialisations, as would be the case here, the QCTO would probably insist on a qualification consisting of a series of part qualifications.

Conclusion

This chapter has summarised the various options for developing qualifications to address the training needs.

In general one has to conclude that the industry is too small to support conventional formal training programmes. At best, for the foreseeable future, it would seem that the industry would have to rely on on-job and ad hoc training to develop its capability.

However, there are perhaps other options for training. These are discussed in the next chapter.

Chapter 7 – Learning and Qualification options

Introduction

The previous chapter summarised options in developing qualifications for advanced composite manufacturing, specifically at the semi-skilled and skilled level. The chapter also summarised some of the difficulties inherent in the development process and raised the question of whether these qualifications could address the needs of advanced composites in the context of the larger industrial FRP industry. This chapter considers these issues and considers other ways of achieving qualifications which would suit the industry.

Why develop national qualifications?

The key arguments for developing national qualifications are that they standardise training across accredited training providers and workplaces, and provide consistency of assessment, especially of the final summative assessment.

Against this view there is the argument that national qualifications are less flexible and so less able to deal with contextual variations or to change the training process if technology or new development changes the way work is done.

The accreditation system essentially is there to protect learners and employers from unscrupulous providers and to ensure that training meets the required standards. However, accreditation of training providers can also lead to a greater focus on conformance to ensure that their accreditation is maintained. Some of these conformance requirements may add little value to the overall training and can make the process more costly. Rather than addressing learners' and employers' real needs the training results in mediocrity.

The national system still emphasises the provider as the key element of the learning process. However, provision is only a small element in an overall learning process. Social learning (from coaches, mentors, fellow employees) and workplace learning (from practicing and being challenged by the work itself) are key ingredients to developing proficiency but do not figure much in the formal, accredited system.

The next section deals briefly with developments in our understanding of learning in and for work.

Learning trends

The erosion of the front-end model of vocational preparation

> *We use the term 'front-end model' to refer to any instance of vocational preparation that is based on a period of formal education and/or training that needs to be completed by entrants to the occupation before they can be regarded as qualified workers. The formal education and/or training usually takes place in classrooms remote from the workplace (Becket and Hager. 2002:99).*
>
> *Practice as the basis of learning at work, …, can be regarded as a new beast in the educational landscape. However, it is not a recent arrival: it has been there all along without being noticed. Practice, and the informal learning that accompanies it, have gone largely unnoticed because they do not fit easily into what has been the dominant educational paradigm…*
>
> *At the same time as practice-based learning at work is suddenly receiving prominent notice, one of the major planks of the dominant educational paradigm, viz. the front-end model, is showing clear signs of collapsing (ibid:101).*

The front-end model is also embedded in most formal, credit-bearing training practices. What is needed are alternative models, frameworks or approaches.

The 70:20:10 framework

One such alternative is the 70:20:10 learning framework model. This has attracted much attention and some debate in the learning and development community world-wide. In this framework learning is subdivided into three modalities, where:

- 70% represents learning obtained by experience and practice through tasks and assignments that stretch the learner
- 20% represents learning obtained through other people, role models, conversation, networks, reflecting on experiences

- 10% represents learning from formal programmes, books and on-line resources

It is critical to note that these numbers are not meant to be absolute – they simply provide degrees of emphasis.

The 70 and 20 are largely informal learning – that learning which happens in context and not in formal training situations. Novices will probably require more than 10% formal resource-based learning. However we must not fall back into the front-end model as a form of provision. Many learners increase their understanding by having the formal learning come after exposure to the work context.

Short(er) learning interventions

Another trend has been to break formal learning down to bite-sized chunks. These are variously known as micro lessons, learnlets, drip feed learning, speed courses etc. Older forms of such short forms of learning include one-page or one-point lessons which originally were developed for autonomous maintenance processes, green circles etc.

The learner can also receive such short learning interventions on a mobile device, tablet or computer. The lesson may be in the form of a short presentation, text, infographic, game or video. Learning that is spaced out has a greater chance of being remembered. Even university students have difficulty recalling material which they heard or saw 30 minutes into a lecture.

But as above such injections of information need to be coupled with other activities, preferably with discussion in the team and application in the workplace.

Combining hard and soft skills

Quality improvement programmes, such as lean or world-class manufacturing, couple hard skills with the development of soft skills such as communication, planning, evaluation, inter-personal skills and team work. The use of thinking tools such as De Bono’s Plus, Minus Interesting or the Ishikawa (fishbone) diagram for root cause analysis are also ways of combining hard with soft skills.

Changing the learning paradigm: from content to activity

Much of the work being done in designing learning programmes is to shift the focus from content to learning activity. What are the learners going to do? By structuring a suitable set of activities, learners will be able to assimilate the knowledge required along the way. A simple example of this would be to replace a day-long, PowerPoint-driven training session on hazardous materials in the workplace, with the facilitator giving employees a set of Material Safety Data Sheets (MSDS) and structuring learning activities around the interpretation and classification of the information contained in the various MSDSs.

The QCTO curriculum model

The QCTO curriculum model of knowledge, practical skills and work experience modules can also be applied to shorter and more informal learning programmes. The model is especially useful for new products and changes in the process.

SAQA policy of learning not for credits

In March 2016 SAQA published draft "Guidelines for Good Practice for Learning that does Not Lead to a Qualification or Part Qualification (LNQ)". This document creates some space for developing non-NQF, non-credit-based learning. The guidelines have not been signed off yet. They are still problematic in that they are still very provider-centred rather than learner-centred and in that they involve Quality Councils. But they do create the space for adapting and tweaking learning programmes which may be required for "just-in-time and just-enough learning to meet a specific need for a workplace or similar environment" (SAQA, 2015:8) by creating a "Peer evaluated self-regulation model". This model is still based on a group of accredited providers forming an "Organised Constituent Provider group". (SAQA, 2015:9)

New trends in credentialing

Internationally, there in now an increasing interest in:

- Micro-credentialing, e.g. digital badge, open badges

- Retaining (professional) designations (Continuous Professional Development or CPD) or occupational certifications for the performance of certain types of job.

Micro-credentialing – digital and open digital badges

Digital Badging is beginning to evolve rapidly to fill the gaps in recognising learning and providing an alternative model to monolithic courses. The badge represents an achievement. It is similar in concept to Scouts collecting cloth badges or pins, achievements in computer gaming or awards for achieving fitness milestones or targets.

Because they are digital, they can be shared and displayed in on-line backpacks.

Open badging

The following is an adapted version of a presentation made by Rianna Crafford to the Learning and Development Committee of the South African Board for People Practices (SABPP) on 13 July 2016

Open Badges refer specifically to badges that adhere to an open standard being led by Mozilla for recognizing and validating learning. Mozilla is a community of software developers which develops standards and free and open source software for products related to internet usage. It is best known for the Firefox web browser. Open Badges are secure, web-enabled credentials that contain granular, verified information consumers can use to evaluate the capability of the badge earner.

They require:

- An issuer, the authority that issues the badge
- The badge itself, hard-coded with meta data
- The user/earner, the learner, the worker, the employee
- A platform, e.g. Mozilla Open Badges, the display site
- The backpack, the individual's collection of the badges s/he wants to display
- The consumer, the party interested in the people (the badge earners) and the achievements.

The badges themselves are dependent on:

- The awarding criteria
- The evidence requirements to meet those criteria
- The expiry date (length of the validity).

The badges themselves are hard-coded metadata (somewhat akin to a composite product – they are baked in).

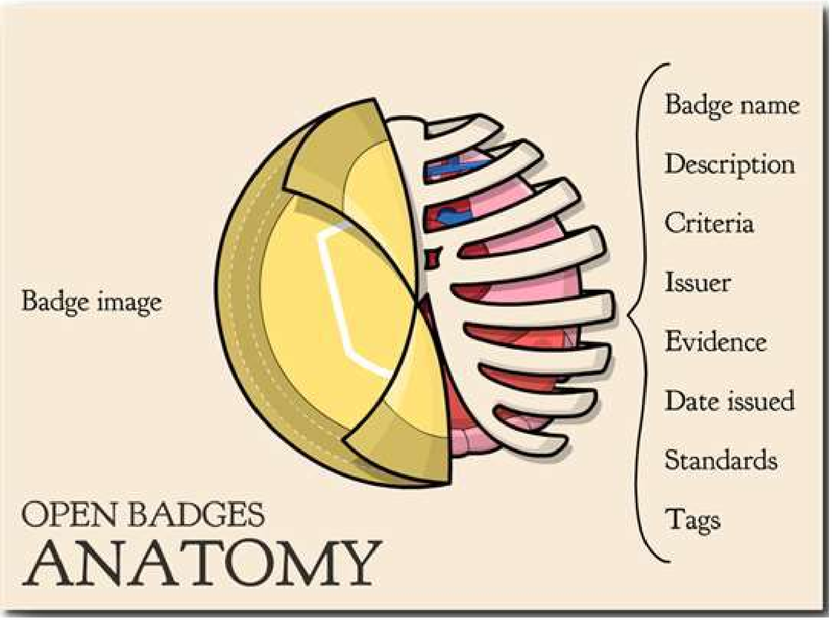


Figure 8: The Open Badge Metadata

Open badges require IT infrastructure to house and display the open digital badges. The following components, like an advanced composite product are "baked into" the badge:

1. The issuer – the authority
2. The earner (learner)
3. The badge with its metadata
4. The displayer (or system) of storing and displaying
5. The earner's backpack(s) of selected badges
6. The consumer who may wish to view and evaluate the earner's badges

Open digital badges recognise a wide range different types of achievements, for instance:

- Attendance

- Endorsements
- Milestones
- Membership
- Accredited
- Certified
- Participation
- Mastered
- Subject-matter expert …

Digital badges can also be sequenced into levels to create learning and qualification pathways. They can be used for micro achievements and for macro achievements. Other benefits of digital badges are:

- They rely on pull-learning, not push-learning processes
- They allow flexible learning
- They are a lean start-up solution – they can start small and be built incrementally
- They provide instant feedback and tangible short-term rewards, building energy and competitiveness.

Conclusion

The traditional approach to training does not work effectively for the advanced composites industry. The numbers are too small to create sustainable training schemes. Currently the advanced composites industry uses a great deal of short non-formal and informal training which falls outside of the NQF.

Developing formal qualifications in addition to or included in FRP qualifications may be difficult and time-consuming. The industry needs a flexible training scheme which can adjust to specific challenges in the workplace. It can achieve this by:

- building on what already exists in terms of training
- using standard work practices
- linking to certifications in other countries
- developing shorter and more context-specific training programmes
- linking the whole to an alternate method of credentialing.

Chapter 8 – Proposals and Recommendations

Introduction

The nature of the industry

What is clear from the study is that the advanced composites industry faces some unique challenges. Using conventional approaches to the development of skills is not going to be an effective strategy.

The following factors make the development of a conventional strategy difficult:

- The industry is relatively small, employing only a few thousand employees
- The industry's customers fall into a number of different sectors, e.g. manufacturing, chemicals, transport, defence etc. This means that individual manufacturers may have to satisfy a variety of process qualification criteria.
- The wide range of products and processes mean that the required skills vary considerably and make it impossible to develop any standardised qualifications and training solutions
- The industry lies in the *complicated* to *complex* domain of the Cynefin framework – this again means that solutions are not always self-evident and that some level of experimentation is required. The industry is constantly innovating new products.
- Technology is constantly changing and new materials, processes and equipment impact very quickly on industry practices – this means that re-skilling needs to be factored into the skills development strategy
- As polymer composites are introduced into other sectors, so other occupations are going to have to become proficient in working with polymer composites. Having some generic training components may assist these industries and the affected occupations.
- Process qualification and the certification of personnel for that purpose is a key driver for creating an industry-recognised training scheme.

As mentioned in Chapter 1 the industry straddles the boundaries of the *complicated* and *complex* boundaries of the Cynefin model. Professor Snowdon's recommendations

(Snowdon, 2015) for solutions in the *complicated/ complex* space rely on collecting evidence through small “safe-to-fail” experiments, dampening those that do not work and amplifying those that do.

The recommendations that follow are made in this spirit.

Changing education and training practices

As discussed in Chapter 7 the front-end model of vocational preparation is slowly being eroded. Secondly, to implement a trade qualification or even a fabricator level qualification will take several years. Thirdly, the training needs vary considerably so that a single homogeneous training programme will be wasteful and inefficient.

What is needed is a flexible, needs-driven programme informed by workplace needs. Once the training in this model has been adequately tested and refined it can then be aggregated into formal, registered qualifications.

Combining the QCTO model with open badges

Recommendation: Structure small training interventions using the QCTO three-component model and then recognise the achievement of outcomes with open digital badges.

The three-part QCTO learning model of conceptual knowledge, practical application, and workplace implementation could be used as a framework for advanced composites digital badges. The key outcome would be the ability to apply the learning in the workplace on a consistent basis while meeting the workplace quality criteria.

This does not mean that the training has to be dumbed down. By using an activity-based approach the training can develop cognitive thinking skills as well. Switching the focus from learning “content” to applying concepts and thinking tools in a developmental activity changes the learning dynamic quite dramatically. It enhances the notion of pull-learning i.e. learning that is just-in-time and just-enough.

Standard Work Procedures and related standards

Under the auspices of the Advanced Manufacturing Technology Strategy (AMTS), industry has already developed a series of Standard Work Procedures (SWP) (see Appendix 2 for an example of such an SWP). Each of these could be linked to one or more badges. This would create a simple form of certification.

These SWPs could also be cross-referenced to the National Occupational Standards developed in the UK (see Appendix 3 National Occupation Standard EMCOMP208 Prepreg laminating as an example.)

Regular re-assessment can form the basis of badges for continuous professional development. These badges could be used by an individual to maintain the certification process. Badges can be tailored for specific processes and products. Badges can be sequenced so that they can be combined into a larger badge. The earning process can largely happen at work. The assessment in most cases would relate to achieving a work related outcome. This provides value to not only the earner, but also the employer.

Some advantages of open badges for advanced composite achievements

The badging can be a very simple system to develop and administer. The badges themselves could be designed to reward "baby steps" in the early phases of learning in order to encourage and engage earners.

Providers can still continue offering larger components which will ultimately lead to badges but they could also get involved in generating smaller bite-sized chunks of learning. This could generate an income scheme.

Suppliers who support the industry with training could also become "providers" and have their role recognised.

As the scheme evolves it will become clearer what national qualifications are required.

The local issuer could negotiate recognition from international composites bodies for co-recognition of selected badges. Associations such as the American Composites Manufacturers Association, the Fraunhofer Academy or the Composites UK form potential partners.

Some of the challenges in implementing open badges

The traditional training provision is so deeply embedded in the psyche of the industry that a proposed implementation of open badges is bound to lead to confusion and objections. It raises the following questions:

Who would become the issuer? In the absence of an active industry association one would have to set up a body (see recommendations for a possible solution). The body would also have to host the badging system. The Mandela Bay Cluster has yet to form a skills committee but it offers the industry the opportunity to tackle the problem on a joint basis

Recommendation: Set up a joint team within the Mandela Bay Composites Cluster to design and administer the badging scheme. The team could consist of cluster staff, provider representatives including universities and research facilities, and SETAs. The initial SETA would be MERSETA.

For higher level courses the involvement of the Council on Higher Education could be considered.

Include a badging specialist in the initial team. There are a handful of knowledgeable people in South Africa. I would suggest Rianna Crafford who has completed a master's thesis on the topic of open badges – see http://www.slideshare.net/RianaCrafford/open-badges-south-africa-badging-guidelines. The computer infrastructure would also need to be hosted locally. This would require a partner company. A number of companies are ready to invest in this infrastructure if a commercially viable and sustainable project could act as the trigger.

Contact details to both Rianna Crafford and a potential partner company can be provided.

Recommendation: Build a research and evaluation programme into the scheme from the outset along the lines that MERSETA and the University of Bremen have pioneered with artisans.

How can such a scheme be managed as it falls outside the NQF?

Badges would require an alternative form of accreditation. This is also important because the workplace is an integral part of the overall process. In the QCTO system workplaces are not accredited, only “approved”. The accreditation criteria need not follow the NQF model which emphasises the content (the manual) and the location of the training (the premises). For badges the accreditation criteria should emphasise the learning process.

Badges would also mean negotiating a special agreement with relevant SETAs to be eligible for grants.

It may take learners and providers a while to get used to the concept.

Implementation of the badging scheme

The implementation of the badging scheme need not be an extensive and high risk endeavour. The philosophy should follow lean principles. The continuous improvement or kaizen approach should be built in.

Recommendations: Begin with the coalition of the willing, the current actors and the current training programmes and processes. Test the scheme with what is already there and working. Refine the programmes based on the tests. Where possible link the badges to national strategies to showcase the interventions.

Further recommendations to test the scheme and gain support include the following:

- Take learning to the employees where practical and cost-effective
- Structure some of the current formal and informal skills programmes into badges
- Structure the proposed set of higher level courses (van Rijswijk, 2015) as badges to test out the badging concept at this level
- Tweak current courses to create greater learner engagement and test the use of mobile and video technology to enhance the delivery
- Only take employees off-site when they can gain from cross-fertilisation or special knowledge
- Brand the badges to make them “sexy”, e.g. carbon-fibre digital badges
- Develop some standard learning material (e-learning, m-learning, v-learning) that is short, sharp, targeted and widely applicable
- Promote the concept of badges and certifications to external authorities for certification purposes, e.g. the Rail Regulator

- Develop badges, not only for individual tasks, but also for more holistic competencies which integrate the technical with the broader sets of capability, including, problem-solving, design thinking, advanced manufacturing mindset, teaching/training of others etc.

In passing, the engineering faculty of Wits University and Wits Commercial Enterprise (a wholly owned Wits University entity) are exploring third stream income opportunities. One of these is focused on developing links with the QCTO and the Occupational Qualifications Sub-framework of the NQF. The engineering faculty also has a composites research facility. There is already a funding relationship between MERSETA and WITS which could be usefully exploited in developing possible solutions.

In addition, I discussed some of the proposed recommendations with Dr Tim Hutton of Wits Enterprise. He has developed a method of developing and getting approval for short courses within a period of six weeks. He has also developed a revenue sharing model for these courses. This linkage for the higher level courses could provide a level of recognition if required. (Dr Hutton also has a personal interest in advanced composites. He is a master rower and manufactures hulls and paddles.)

Conclusion

This study began with a skills mapping methodology which fell in the *obvious* domain of the Cynefin model. The methodology did not entirely hold and further investigation showed that skills development challenges in this sector are complex and there are no simple answers.

The industry itself thrives on innovation, often operating at the cutting edge of what is possible with materials and manufacturing processes. Research and implementation of the research are very closely linked.

The proposed approach to training follows a similar philosophy. It is based on building on what is already there and using innovative methods to recognise learning achievements.

The greatest benefit of the proposals is that the scheme could be set up tomorrow.

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Appendices

Appendix 1 – Skills profiles

Appendix 2 – Appendix 2 AMTS-SWP-0008-F-2010-Prepreg materials

Appendix 3 – Appendix 3 National Occupation Standard EMCOMP208 Prepreg laminating