COMPOSITE TOOL DESIGN

and Manufacture for Closed Moulding

A 2013 International Specialised Skills Institute Fellowship.

PHILLIP BOVIS

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i. Executive Summary

This Fellowship enabled Phillip Bovis to research the international composite industry with respect to advances in closed moulding processes and tooling. The challenges to current manufacturing activities in Australia are such that we need to produce goods smarter and faster to maintain current footholds in global markets. This can only be achieved by comparing existing practices to those considered to be best practice overseas and updating methodology when necessary. Currently, the perception is that we are often several years behind the rest of the world in adopting new processes and using new materials.

2013 was the first year that the Certificate III in Engineering (Composite Trade) was delivered. The qualification has been one of only two apprenticeships endorsed by the Victorian Government in the last 50 years. This highlights two points. First, that composite materials and processes are being accepted into all industry sectors, and second, that stakeholders have realised that training was the key to lifting the profile of the industry to meet future needs.

Many of the apprentices had little knowledge of the overall processes or materials they were using when they started. Currently many workers in the composite industry are treated as process workers. At a recent symposium on Light Resin Transfer Moulding (LRTM) it was identified that there were not enough able tradespersons to meet the tool-making needs currently required as open moulding shifts toward closed moulding. Global pressures on production targets means companies are looking very closely at maintaining repeatable output targets in order to keep the doors open. Faster lead times to produce tooling will be the key to successful production schedules.

The Fellow investigated the strategies employed in the United Kingdom (UK) and United States of America (USA) to produce tooling for closed moulding, and compared methodology, materials, design and engineering capabilities to those employed in Australia - in particular Victoria. He also compared our current training methodology with that of overseas community colleges and universities, to see if there is was shift in the way apprentices are trained.

Tangible benefits for the industry are occupation and the Fellow’s vocational enhancement.

The Fellow believes he will be able to share with industry many points of view as to how tooling is engineered and what challenges overseas industry faces from a local and global perspective. He has also researched materials not currently used in Australia or to be able to show how existing materials are being used in less conventional ways to gain market advantage.

There are processes that the Fellow arranged to view that have not yet been demonstrated in Australia. Overall, the Fellow believes that the knowledge he gained can be demonstrated back to industry and his apprentices so they can try the next step in developing a level of innovation that helps their respective companies. His findings overseas will enhance his ability to assist local industry in developing comprehensive training schemes that will help them remain competitive.

As a member of Composites Australia, the Fellow will be in a great position to further assist any company who wishes to accept alternative methods to their current practices in developing closed moulding processes. He will present the majority of his findings at industry briefings for Composites Australia (CA) and Society of Plastic Engineers ANZ (SPE).

ii. Abbreviations & Definitions

AFI	Australian Fabricating Industries
AMCA	American Manufacturing Composites Association
CA	Composites Australia
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CAM	Computer Aided Machining
CERL	Composites Engineering and Research Laboratory
CMM	Co-ordinate Measuring Machine
CNC	Computer Numerical Control
CCP	Cook Composites and Polymers (now owned by Polynt)
CFM	Continuous Filament Mat
CCT	Certified Composite Technician (training course)
CSM	Chopped Strand Mat
EEC	European Economic Community
EEDF	European Economic Development Fund
EPD	Environmental Product Disclosure
HESG	Higher Education & Skills Group
ICS	Innovative Composite Summit
LCA	Life Cycle Assessment
LRTM	Light Resin Transfer Moulding
MSA	Manufacturing Skills Australia
NCC	National Composites Centre
PET	Polyethylene terephthalate
PLM	Product Lifecycle Management
PVC	Polyvinyl chloride
R&D	Research and Development
RIM	Reaction Injection Moulding
RPL	Recognition of Prior Learning
RTM	Resin Transfer Moulding
RTO	Registered training Organisation

SMCC	Southern Maine Community College
TMC	Temperature Controlled Moulding
UHMWPE	Ultra High Molecular Weight Polyethylene
VIP	Vacuum Infusion Process
VOC	Volatile Organic Compound
psi	pounds per square inch
kPa	kilopascals
inHg	Inches of Mercury

General Definition

To assist in understanding the background of this Fellowship a brief explanation of what composites are is necessary. Products range from a boat made from fibreglass to helmets, sporting goods or car accessories made from carbon fibre or Kevlar. These are reinforcement fibres. They are combined with different liquid resin types into a mould to produce the required parts. Once the resin has gone through a chemical reaction, it hardens. The solid part is then released from its mould. The part may be a singular piece (e.g. helmet) ready for market or joined with another part to form an assembly (e.g. boat). Depending on the complexity of the part, the mould can be equally as complex. The moulds are usually formed from patterns called plugs which replicate the part required.

In the recent past, most of these parts, components or assemblies have been laid up using open moulding or vacuum bagging techniques. Legislative pressures in reducing Volatile Organic Compound (VOC) emissions globally has called for a level of innovation resulting in defined processes as closed moulding. The resin systems release very minimal to no vapours as they are pumped or sucked into the mould cavity. Processes include Resin Infusion, Composite Closed Bag Moulding (CCBM), Flex Moulding, Light Resin Transfer Moulding (LRTM) and Resin Transfer Moulding (RTM).

These composite processes use reinforcement fibre materials made from glass, carbon, aramid, polyester, polypropylene, boron, and natural fibres jute, flax and kanaf. They can be arranged into woven cloths or be stitched. Fibreglass is predominately used in open moulding as a chopped fibre that is applied off the roll or chopped at the head of a chopper gun (a production tool). Resin systems are generally epoxy, polyester, vinyl ester, phenolic or blends of. The resins are used for laminating, gel coating and tool building. Core materials provide through laminate strength through thickness without adding weight. These core materials are made from Polyvinyl Chloride (PVC), Polyethylene Terephthalate (PET) and urethane foams, honeycombs from phenolic coated paper, plastic and aluminium, balsa wood and plywood.

Parts are created from moulds which are in turn created from plugs (patterns). Plugs are developed from drawings. Computer Aided Design (CAD) drawings can form information that Computer Numerical Control (CNC) machines can interpret to cut foam, wood or tooling board. Metal moulds can be also cut from the same CAD data. Parts may require post trimming but many aspects of closed moulds allow the provision for the part to come out of the mould without any finishing requirement.

Component Definitions

A mould:

Main part of a closed mould system. It will have a wide flange for the setup of a sealing system. The width of the flange is dependent on the projected area of the part, so that seals systems can be setup to provide a clamping force.

B mould:

Also has wide flanges that match the A mould to facilitate the seals. It would have the thickness of the part taken from it so when it is in place it provides a cavity. Would also have resin inlet ports and vacuum ports. The B mould can also be made from silicon bagging material.

Additive:

A substance that may be added to a resin system to assist gelation or curing properties.

Autoclave:

An oven that can apply heat (up to 250°C) and pressure (up to 100psi) to the outside of a bagged laminate. The laminate will have vacuum pressure applied to the bag of -14.7psi.

Bagging material:

Usually refers to consumable bagging that is used only once. This material is usually made from nylon or with other polymer blends.

Clamp force:

The force required to clamp the A mould to the B mould using vacuum pressure. This force is dependent on the projected area of the mould surface. The force required will determine the width of the clamp flange.

Clamp surface:

A wide flange that is built into the A and B moulds that enables the placement of seals. As to A & B mould close together, the seals allow vacuum to be applied to hold the mould halves in place to resist the force of the injected resin.

Closed moulding:

The layup is closed off with bagging or B moulds and vacuum is applied to consolidate the matrix by eliminating and air that might be trapped in the mould, Vacuum bagging, pre-preg, CCBM, Resin Infusion, LRTM, RTM, These processes uses all resin systems and all reinforcement arrangements

Composite:

A laminate made from a mould with 1 or more reinforcements that is consolidated in a resin which has the air removed from it to produce a lightweight, structurally strong component.

Composite material:

A material that is used in a composite layup. These are the resins, reinforcements, fillers, cores or adhesives used in the manufacture of composite components.

Composite matrix:

When a catalysed resin is combined with a reinforcement to form a composite laminate. The matrix is seen as a ratio of resin to reinforcement which can also include filler materials.

Core materials:

These are materials that provide through laminate strength. The core usually have a reinforcement layer either side of it. They are made from polymer foams, phenolic coated paper honeycomb, polypropylene honeycomb, aluminium honeycomb, plywood, balsa and core mat.

Distortion:

Can occur when the shrinkage occurs at the edges of a laminate can also occur when the laminate stack is not balanced.

Exotherm:

Highest temperature that the chemical reaction between resin and catalyst achieve after gelation.

Gelcoat:

A protective surface resin for parts and tooling. More impact resistant than normal laminating resin and provides the coloured surface that most composite laminates have.

Lay-up:

The order in which the reinforcement component of a laminate is arranged, more to do with the weight of the layer.

Laminate:

The arrangement of the layup taking into account the fibre quantity and orientation relative to the resin used to consolidate the form.

Orientation:

The direction a layer of reinforcement may be placed to gain the most strength. Woven or stitched non-woven cloths come off the roll, usually at 0° and are cut to gain orientation angle of 90°, +45° & -45°. Some reinforcement suppliers can provide orientation angles of 20°, 30° and 60°. The fibre pack or stack maybe in balanced or in an unbalanced arrangement dependant on the laminate need.

Outward flange:

This term relates to the edge of the mould which changes the direction of the part. The purpose of a flange when laid up is to focus the shrinkage that occurs during curing. This shrinkage pulls at the corners and often this edge is trimmed after curing so that the edge is straight.

Reinforcement:

Usually synthetic fibres made from carbon, aramid, glass, polypropylene, polyester & basalt. Natural fibres are not so common but are commercially available as in jute, flax, kanaf and bamboo fibres.

Resin:

A substance that reacts with a catalyst or hardener to form a matrix with the reinforcement. They are Polyester, Vinyl Ester, Epoxy, Phenolic and specialist blends that allow the laminate to operate in challenging environments.

Resin choke:

On LRTM moulds, it's an area between the resin gallery and the reinforcement designed to slow the resin progression through the layup until the resin galley if full. This insures that the resin will flow evenly. In resin infusion, it is the area at the end of the reinforcement designed to stop excess resin entering the vacuum lines, by placing a reinforcement that slows/stops resin progression but still allows vacuum suction. CSM and core mat are commonly used.

Resin inlet:

Relating more to closed moulding where the resin enters the closed mould. Size is determined by flow characteristics of the reinforcement stack.

Return flange:

The opposite of an outward flange but not as common. This feature however will be more easily achieved with the LRTM process.

Reuseable bag:

Usually refers to silicon bagging.

Sealant tape:

A tape made from temperature resistant butyl mastic used with bagging material to create a vacuum seal.

Shear:

When heat and friction combine to slowly breakdown the bonds hold the resin together effectively thinning the resin down.

Shrinkage:

This occurs when the resin cures. Some things can affect the amount shrinkage, some of these conditions are how much styrene may in the resin, how much resin is used relative to the reinforcement, temperature affecting exotherm.

Spiral flex:

A plastic tube that is cut in a spiral pattern is used to define vacuum tracks or resin input for resin infusion and forming silicon bags.

Undercut:

This term relates to a mould that will not release its part without relief. The relief occurs with strategic splits in the mould making the mould very complex in nature. Other ways of dealing with undercuts is to create a removable insert.

Vacuum outlet:

Usually placed in the centre of the flow length but not necessarily in the centre of the mould. It is a point where the resin is sucked to from the resin inlet. The outlet is positioned in the majority of moulds in a place that will not be seen from a cosmetic point of view.

Vacuum pressure:

A negative air pressure. In most cases used up to -14.7psi, -103 kPa, -1 bar or -29 Hg. Used in Vacuum Bagging, Resin Infusion, CCBM, LRTM and RTM processes.

Viscosity:

A resistance to flow, measured in centipoise (cp). Thicker consistency in a resin may be more suitable for hand laminating and bonding while thinner consistency resins could be used for processes like resin infusion or LRTM.

Process Types

CCBM:

Composite Closed Bag Moulding uses a silicon bag in a process very similar to resin infusion, using vacuum suction to wet out the fibre stack.

Closed moulding:

The layup is closed off with bagging or B moulds and vacuum is applied to consolidate the matrix by eliminating and air that might be trapped in the mould, Vacuum bagging, pre-preg, CCBM, Resin Infusion, LRTM, RTM. These processes use all resin systems and all reinforcement arrangements.

Flex-Bagging:

Again silicon bagging is employed to create the B mould. The difference in comparison to CCBM is that sensors are employed to relieve flow pressure. Resin is dispensed via a pump.

LRTM or RTM Lite:

Light Resin Transfer Moulding use moulds made from composite materials predominately glass fibre. It uses high pressure vacuum to clamp & low pressure vacuum to assist resin flow which is pumped in with low pressure.

Open moulding:

A process that mainly uses glass reinforcements with polyester and vinyl ester blended resins. Most tooling is made using this process. Using hand laminating or chopper gun as a high production tool. Chopped Strand Mat is the predominant reinforcement used in open moulding.

Pre-preg:

Where the resin has already been applied to the woven reinforcement. However, after the cloth has been applied to the mould, it will require further processing to produce a cured laminate. This is usually done with heat or UV light. These material are stored in freezers or dark areas. These lay-ups also use vacuum to consolidate the part.

Resin Infusion:

This is a closed moulding process where the fibre pack is loaded into the mould dry, a bag is then prepared and sucked down so vacuum can be achieved. Resin is then pushed through the fibre stack with air pressure until wet out. The resin is shut off but the vacuum is still applied until the resin has cured.

RTM:

Resin Transfer Moulding uses A and B moulds made from metal. The weight creates the seal and the resin is pumped into the cavity with much more pressure than LRTM. Components can be made much thicker but tooling is much more expensive.

1. About the Fellow

Phillip Bovis has been teaching in engineering and composite studies for the last 12 years at Kangan Institute (formerly Kangan Batman TAFE). Originally from Wellington, New Zealand, Bovis has been involved in most forms of metal engineering. He got involved in composites because the welding certificates that he held would not be recognised at the time he arrived in Australia. There was no such thing as Recognition of Prior Learning (RPL).

So not wanting to go back to night school for another five years to achieve his certification, Bovis decided that he would learn all he could about carbon fibre in the hopes that he could build a race-car chassis. Before he knew it, Bovis was half way through an Associate Diploma in Engineering. His journey into composites has been one spanning 22 years.

For the last six years, since joining the Board of Composites Australia, the recipient has been working with industry and MSA in developing a trade qualification which became nationally endorsed in April 2012. He was also able to assist the Victorian Government in having the qualification recognised as a trade qualification in Victoria and is assisting RTOs in Western Australia with their claim for the trade.

The future is quite bright for composites in general. Bovis is keen to see Melbourne become the centre of composites manufacturing and training for Australia. In addition, he also intends to work toward licensing of our tradespeople with an endorsement program that will assist specialisation into every industry sector.

2. Aims of the Fellowship Program

After attending many conferences and industry briefings throughout Australia, there seemed to be an underlying problem with the perception of Australian composite manufacturing capability.

The main aim of this Fellowship is to compare existing composite toolmaking practices in Australia to those overseas. The greater part of the problem is reducing lead time to market as most of the downtime associated with manufacturing any tooling is in the build-up of the tool.

The following are some specific points the Fellow has attempted to address as part of his Fellowship:

- Discover the extent of innovation in closed moulding tool design
- Discover the extent of innovation in the closed moulding processes, in particular LRTM
- Establish a clear set of design parameters that determine design considerations when developing composite products and their tooling or moulds
- Compare the way trade training is done in other countries involved in composite production, to better understand the challenges of coping with process updates and tool/mould development
- To look at materials, to see what is being developed to meet environmental/ sustainable policies and regulations.

3. The Australian Context

3.1 A description of the industry

Currently, the composites industry is an unknown quantity and its capability is adjusting to the requirement of composites being used in all industry sectors. Composites manufacturing is experiencing greater growth than most other forms of manufacturing currently in Australia.

Against many other traditional trades, composites are still thought of as a cottage industry due to the older practices they still use. Measuring aspects of material and time usage against those older practices has revealed that techniques will need to improve if manufacturing is going to meet the needs of a growing industry. Many components that would never have been considered are now possible to be manufactured due to closed moulding.

3.2 How the need for additional skills was recognised

Our ability to manufacture tooling is limited due to the embracing of older methodologies and misconceptions about the new technologies. To a degree, this has been brought about by a low level of expertise on the part of the material suppliers who promote these technologies.

Based on his involvement in the industry and participation in local and national conferences, the Fellow's opinion is that the Australian industry is approximately five to six years behind the rest of the world in the application of current technology. This means that industry may be reluctant to invest in technologies that could reduce costs.

Often when businesses are developing their systems and processes, they are reluctant to share any information about what they doing for fear of losing the work to less sophisticated processes. The industry is driven by cost and with less emphasis on quality. The need to improve quality and reduce labour costs is only achievable by introducing closed moulding processes. The processes will trend away from an operator dependency to that driven by tooling lead time. This again is dependent on the ability to manufacture tooling.

3.3 Discussion of the benefits in obtaining the skills and/or the threat of not obtaining them

With the emphasis on tooling, the Fellow has aimed to confirm whether or not tool manufacture is taking the direction of hand built tool using modified resin systems not available in Australia or if CNC technologies are more prominent in tool construction.

Are overseas tool manufacturers using reverse engineering techniques to rebuild tooling? If this information is known, it may set up dialogue between industry and government to change training strategies to follow a similar direction. This would certainly help our composite manufacturing ability maintain or enhance our current position as regarded by overseas.

4. Identifying the Knowledge and Skills Enhancement Areas

There are examples of areas in Australian industries where there are weaknesses in innovation, skills, knowledge, experience, policies and/or formal organisational structures to support the ongoing successful development and recognition of individuals and the particular sector.

The focus of all ISS Institute Fellowships is on applied research and investigation overseas by Australians. The main objective is to enable enhancement and improvement in skills and practice not currently available or implemented in Australia and the subsequent dissemination and sharing of those skills and recommendations throughout the relevant Australian industry, education, government bodies and the community.

The areas of applied research for this Fellowship are therefore defined as follows:

Skill Deficiency 1: Develop LRTM Tooling

» Identify resin systems that are conducive to tooling requirements.

Standard tooling resin systems applied using open moulding methods are still used extensively (Polyester, vinyl ester and blends). CCP do have a resin infusible tooling resin which was developed in Australia but mainly used in USA. The Fellow has already spoken too CCP about training in using the resin.

» Identify techniques for calculating port positioning.

Measuring along the longest flow lines then halving the distance still seems to be the best way to mark the centre vacuum port. But this is sometimes governed by the aesthetics of the part meaning the port can't be put in a place that will be seen in the finished part. At the other end of the spectrum, there is simulation software that can predict alternative flow-paths called Polyworks. It is very expensive but is worth the money on larger jobs over 15m. Where a vacuum port need to be changed or lifted off the B-mould surface, resin flow toward it can be restricted by manipulating the resin choke to restrict flow.

» Identify methods or techniques for producing cavities using sheet or dough waxes.

Still used for the majority of moulds. The ratio of A moulds to B moulds is usually 4:1

CNC cut shims and A moulds with hand laid B moulds are also becoming common practice in the US. The B mould can be made from Polyester/CSM as it is still more durable than a CNC cut version.

» Identify position of seals and inserts relative to counter moulds.

Inserts and seals have become more uniform, their positions are also formed to fit in recesses in the B mould. There are silicon forms to enable recesses to be formed around them however they are found to allow vacuum leaks when the seals are put in because the laminate shrinks away from the silicon form.

» Calculate vacuum pressure requirement for high vacuum clamp.

Dependent on the projected plan view area of the part.

» Calculate vacuum pressure requirement for low vacuum assistance of resin flow.

Vacuum to the cavity side of the seal is usually 0.5 bar.

» Calculate volume of cavity for costing and analysis.

This is still done during tool trial. CAD data can give a volumetric area of cavity and area of lay-flat that the reinforcement is cut to can be weighed to give potential fibre to resin ratio.

» Investigate use of Resin Infusion for tool creation.

Not used as much as thought but developing momentum in the USA due to styrene emission restrictions.

» Investigate design parameters for tooling.

Many companies are engineering their mould solutions with CAD modelling. Lead times are greatly reduced to that of bespoke hand shaped plugs by either machine cutting the plug or machining the mould directly from metal.

» Investigate use of CAD/CAM in plug and counter-mould development.

The best example of a machine cut plug was seen at Marine Concepts in Sarasota, Florida. A foam bolster was cut 12mm undersize to the shape of a boat hull approx. 20 metres long (4 hours). The bolster is then sprayed with a panel filler to build up the surface to 14mm. This takes some time as layers can only be applied up to 4mm at a time to avoid shrinkage and exothermic blooms. After the filler has cured, it is put back into the CNC machine to be cut back to final size. (8 hours) The plug is then surface prepped with a release system, then laid up. A steel tube frame is fabricated around the mould before it is released from the plug to aid movement when the part gets laid up.

Skill Deficiency 2: Develop Resin Infusion Tooling

» Identify resin systems that are conducive to tooling requirements.

Resin systems are still standard tooling (Polyester, vinyl ester and blends). CCP do have a resin infusible tooling resin which was developed in Australia but mainly used in USA. The Fellow has already enquired at CCP about training in using the resin. Tooling came in solid aluminium mould halves that were cut from billet with included fluid movement channels to control cure.

» Identify techniques for calculating port positioning.

There is software that can predict with a degree of accuracy as to where the porting should be placed – Polyworks. Resin systems are still standard tooling (polyester, vinyl ester and blends). CCP do have a resin infusible tooling resin which was developed in Australia but mainly used in USA.

» Identify changes in the construction of vacuum wells within flange.

The wells are deeper to allow larger volume of resin to enter the fibre stack. Allowances for extra ports can speed the flow of resin but this is usually done on larger parts.

» Identify resin systems that can assist in heating and cooling aspects of tooling. Tooling resin is mixed with either very fine dry sand or fly ash to encapsulate copper tubing placed as heating/cooling lines.

» Research resin systems used for sealing moulds.

Standard isophthalic polyester resins work the best as the resin is cost effective and is actually able to flex enough without fracturing.

» Investigate alternatives materials for composite tooling used in resin infusion. The Fellow saw aluminium tooling with heating ports in the rear of the tooling. He also saw the use of a tooling resin specially designed to be infused onto a plug/pattern. Surface preparation of the plug becomes important more so since vacuum integrity is required to infuse the tool. (Detail Optimax resin).

» Identify vacuum requirements through calculation of requirement.

From what was seen, sizing of inlet/outlet lines were not as important as removing air from mixed resin which can introduce air into the laminate at the resin front. The Fellow saw extensive use of internal mixing heads or air evacuation tanks used inline on resin infusion layups.

» Investigate influence of altitude on vacuum capability.

The Fellow did not see any layups done at altitude.

» Identify methods of creating tooling using resin infusion.

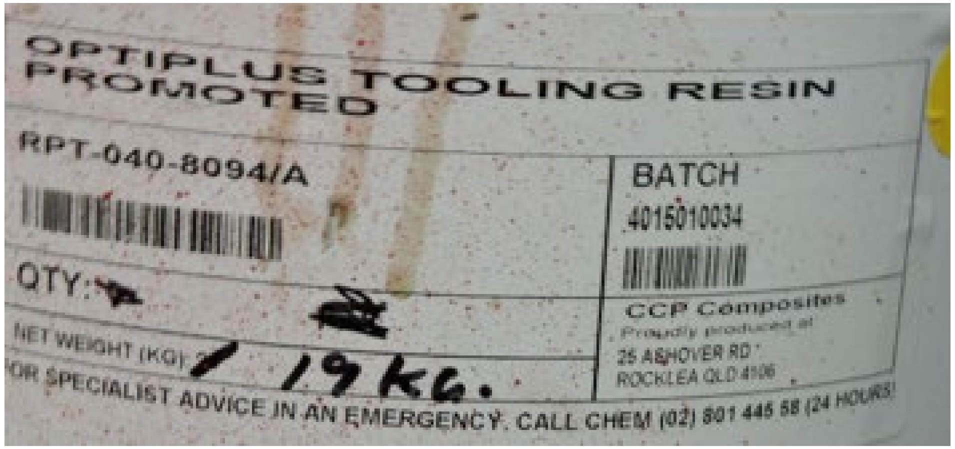


Image 1: Optiplus Tooling Resin Promoted

This resin is available in Australia through CCP Polynt. The resin (Optiplus Tooling Resin) is unfilled but will sustain filling of approximately 30% by weight with 32micron milled fibres. This resin has a low enough viscosity to be used to infuse a tool.

» Investigate the reduction in waste by introduction of caul plates and diffusers.

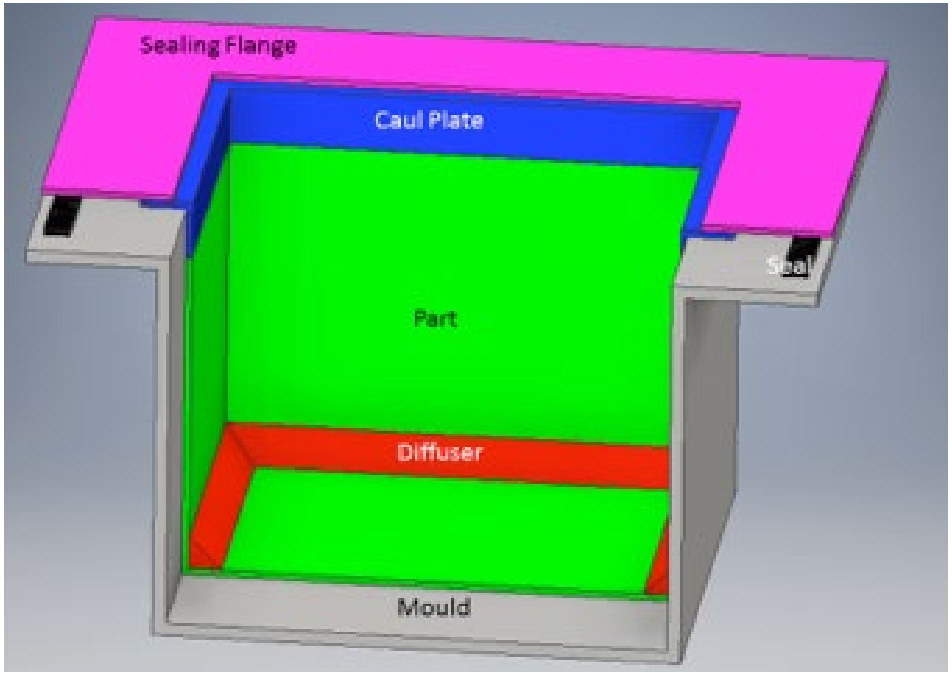


Image 2: Caul Plate

The purpose of a caul plate is to provide a finished edge to the part as it is laid up or shot so that it reduces the need for part edge trimming which is waste. The downside is that they produce an edge that is resin rich as the fibre will be depleted toward an edge.

Diffusers are components that provide shaped pressure under .the bagging material, mainly corners that require the laminmate shape to be dimensional or form stable.

» Investigate approach to prototype tooling.

The Fellow has seen the use of 3D printed core components which then have a woven cloth laminated to either side. These work well after assemblies get scanned and the data is converted into an STL file to form the core.

» Identify process defects relating to vacuum or resin system problems.

Defects generally arrive from air in resin, poor bagging technique resulting in vacuum leaks. Resin systems need to be matched to the process to reduce instances of premature gelling and resins also need to be matched to reinforcements promoting adhesion to fibre.

» Investigate use of CAD/CAM in plug development.

It is common practice to set a foam bolster and then machine the plug to approximately 12mm under size. The plug is then sprayed with highly filled polyester resin to a thickness of 14mm and allowed to cure. This takes about 7 days as it requires to be built up in layers to avoid shrinkage. The plug is then set back up in the CNC machine to be cut to final size. The plug is then finished by hand to take out minor surface scratches. It will then be prepared with release agents ready for a mould to be taken from it.

The Fellow was able to observe, over the course of a day, a preliminary plug cut (about 4 hours for a 20m long form (boat hull) and a finishing plug cut (2.5 hours for a 10m long form (flight simulator)). Comments were made during a training course that lead times could be reduced with the use of a urethane filler which was approximately 4mm thick. When it cures it is strong enough to stand on without deforming the foam support, however this material may be difficult to get into Australia because of the rules maintained by NICNAS.

Skill Deficiency 3: Develop RTM Tooling

» Identify how tooling requirements are constructed.

Techniques used are similar to methods learned in 2007. The difference is the gap between the B mould and A mould flanges is small no bigger than 2mm in depth. The flange limit land is set-up on both sides of the seals to support the flange and reduce flexing of the B side. Seal profiles are relatively uniform and Port fittings are also uniform. The biggest change to mould development has been the introduction of heating/cooling coils to the back of the moulds. This allows for better control of the cure.

» Identify process requirements dependant on size of tooling.

Tool size has a bearing on the process used.

» Investigate surface finish on tooling and how it affects part finish and process.

An “A” class finish is still desirable to assist in resin flow. With both A & B mould optimally finished, both sides can be gel coated. Release systems also play a part in the way resin flow around the moulds.

» Investigate how RTM process differs from LRTM process.

RTM use metal moulds usually cast then machined to final size. The pressure that the resin is injected into the moulds is up to 6 bar. It relies on the weight of the tooling to assist clamping so the mould halves are not pushed apart. Often frames are used to rotate the mould halves while gel coating or loading the fibre stack. Usually overhead cranes are required to lift the mould halves and/or their parts. The biggest part the Fellow saw while in the US was a 5.8 metre boat hull. The mould halve and part required a crane to remove it from the A mould. The fibre stack took 35 minutes to load. Mould filling time was approximately 0.5 hours weighing 300kgs. An hour was allowed for the part to cure. Often the moulds are heated to promote the cure. The part was then put into an oven to post cure further. The part then went to a waterjet cutter to be post trimmed.

Undercuts and return flanges require very complex moulds.

LRTM uses moulds made from composite materials. They are much lighter and often can remove the B Mould and part from the mould manually. Cycle times are dependent on flow mediums within the fibre stack. Resin pumped into the mould is at a much lower pressure, up to 1 bar.

» Investigate design parameters for tooling.

They are the same for tools made for open moulding with extra attention given to seal placement areas.

» Investigate use of CAD/CAM in tool production.

The Fellow saw many examples of metal moulds and foam plugs manufactured with CNC equipment.

5. The International Experience

Organisation: The Northwest Composites Centre (NWCC), National Composites Certification and Evaluation Facility (NCCEF), 20 September 2013

Location: University of Manchester, Manchester, UK

Contacts: Barry Gleave - Academic Support and Facilities Manager

The Centre develops testing and validation procedures for industry related problems relating to products manufactured with composite materials. These procedures are usually developed outside the commercial norm.

The Centre has all sorts of testing equipment to investigate various modes of failure within components manufactured or constructed from composites and/or other polymer based materials.

Housed in the paper science facility, during the visit they were in the process of removing a paper manufacturing machine to make room for more composite testing equipment (beam and long structure testing).

Some of the tests that are being used to validate the fibre were tensile by nature but with the ability to add modular vibration and oscillation while under load to failure. Laminates were arranged with different orientations so the test would be done at least 4 times but up to 16 due to the possible variation in orientation.

They are also able to study the effect of resin systems on fibre which in turn changes the way the industry develops resins systems. Match the resin to the fibre or vise versa. Currently the fibres are doped with binders and sizing materials to match the resin.

Takeaway Learnings:

The Centre is looking to validate as many composite fibres as possible to develop a database. This has two effects on the composites industry which in the past has been controlled by aerospace requirements.

The information on tensile and flex modulus values are known over a range of commercially available fibre. The data compiled may then circumvent the aerospace validation process by comparing validated fibres to non-validated fibres, providing companies with an opportunity to produce fibre for an engineering solution rather than for a closed industry network.

The data could also be used in FEA structural analysis and composite CAD software to assist with the design of structural components. These programs use the data in a specific way based on results of tests such as those done at the centre.

Organisation: South West Composite Gateway, 23 September 2013

Location: City of Bristol, Bristol, UK

Contacts: Jerry Corless – Project Manager and Michael Ilogu – Project Officer

This organisation is located within a community college, like our TAFE system, providing trade training.

There is a collective of industry partners that assist with equipment and materials. They impart knowledge through industry leaders who share aspects of their processes during short courses which the Gateway facilitates. Many of the participants in the course work for GKN, a major supplier to Airbus.

The composite component of the course is only about 20% of the metal fabrication program. Of the 30 students, two thirds are from GKN. The college also offers a number of short courses addressing some of the training need around composites for engineers and technicians. These occur each quarter in frequency. The majority of their funding comes from EEDF, as Europe has recognised that composites have become a major material of consideration.

Staff were able to show the Fellow a class in progress. The students were preparing an infusion layup with similar equipment the Fellow uses in his own training. Their workbenches had built in dust and fume extraction which the Fellow thought was a way of reducing reliance on PPE or dedicated extraction equipment. These were made by Airbench, UK.

Image 3: One of the workshops showing airbenches, curing oven and vacuum equipment.

Image 4: Shows an Airbench which extracts resin fumes and dust, recirculating clean air.

Takeaway Learnings:

Trade level training in the UK experience similar problems to Australia as far as funding, industry experienced trainers and the certification system. Jerry and Michael agreed that the format and unit makeup of Australia's Certificate III in Engineering (Composite Trade) was a better fit for the activities they currently conduct. The Fellow will commit to maintaining a contact relationship with Jerry and Michael to at least keep up to date with industry thinking in the UK.

Organisation: National Composites Centre (NCC), 24 September 2013

Location: Emerson Green, Bristol, UK

Contacts: Nigel Keen – Business Development Engineer

Paul Shakespeare – Skills Lead / Training Consultant

Most of the work at the NCC is still carbon/epoxy – so most of the tooling is metal, steel, aluminium and Invar or carbon/epoxy. The current interest is tooling up for volume high speed press operated both for High Pressure RTM and long fibre thermoplastic injection/stamping. Their current research programs are in methods of getting heat in and out of tools on a rapid cycles and to control the exotherm. Evaluating various tool building strategies is also of interest. NCC have also looked at marine composite plug machining and tool building and recently produced a set of infused epoxy/glass/PET cored moulds. This was for a Class 950 series race yacht. The PET core material was produced in Germany from recycled soft drink bottles.

In the auto sport /niche auto market 'finish straight from tool' in carbon epoxy is of interest to perhaps avoid lacquering, using both hand-lay, infused and RTM light methods. At the low cost/volume end of the FRP market the Fellow has seen a complete switch over the last few years to filled, shrink compensated polyester, usually behind vinyl ester skin laminates. There have also been some interesting tooling products emerge using syntactic foams, although to date we haven't got involved with spray chop, or that kind of process on site here.

The complex is very impressive housing a number of high-end processes that assist engineering students and graduates develop solutions to composite problems through R&D. With a number of industry partners that provide an avenue for graduate engineers to gain experience on real-time problems. The NCC has completed stage 1 and stage 2 has started construction. Examples of some of the equipment NCC runs include a robotic manufacturing cell, robotic tape placement, large CMM capability, 2 large autoclaves, CNC machine centre, diagnostic and analytical equipment, a large layup room.

One thing that the two organisations in Bristol have in common is that the qualifications they train against do not fit the industry need. Both would like a qualification that better reflects the nature of their industry. While Victoria enjoys a new apprenticeship, the respective representatives are keen to look at our qualification to see if it will serve them better than their existing qualification.

Takeaway Learnings:

The level of investment by industry partners was astounding and equally impressive is the amount of money being spent by the EU to set up collaborative communities in composites. This may be why we are seeing a slow transition of knowledge and materials making its way to Australia.

Organisation: South West Composite Gateway, 25 September 2013

Location: Devon, UK

Contacts: Jerry Corless – Project Manager

Jerry Corless of the South West Composite Gateway invited the Fellow to a Lifecycle Assessment of Composites seminar where a number of speakers indicated the different methods for recycling and reusing composite waste. This seminar was held in Devon.

Demonstrations of programs that can calculate embodied energies, emissions trading and other factors that may limit or enhance design of composite components were provided. There was a sense that there is a plan to deal with composite materials although it has not been fully endorsed by the composite industry as a whole. There are indications that the size of the industry will be in a good position to make recycling cost effective. Comparatively, the market in Australia is very small, so similar initiatives will be seriously challenged to be cost effective.

Any products manufactured by, or for use by, the EU now requires an EPD (Environmental Product Disclosure). SimaPro S was the software demonstrated. It enables base data to be developed or derived to allow independent analysis of such a statement to be compliant. The EPD look at all the constituents of a product where the LCA may also be undertaken to provide an environmental footprint (e.g. a plant for producing resins and packaging for shipping compared to a bulk storage facility that decants imported resins down to retail quantities).

Takeaway Learnings:

The Fellow found out that the software was available in Australia. The fact that European composite industry has decided to come into line with other materials used in manufacturing suggests that environmental sustainability will become an important issue in Australia once governments (State and Commonwealth) can develop workable strategies with industry.

The Fellow also met Mr Mark Crouchen, Managing Director of Rockwood Composite and Dr John Summerscales, Associate Professor in Composite Engineering from the School of Marine Science & Engineering, Plymouth University.

Organisation: Rockwood Composites, 26 September 2013

Location: Devon, UK

Contact: Mark Crouchen – Managing Director

Rockwood Composites is a small composite manufacturing facility in Devon. The company produces components predominantly from pre-preg materials. They manufacture their own tooling from aluminium using CNC machine centres from CAD models designed in-house. The components they produce are manufactured for all industry sectors. The majority of their components a quite small (< $1m^2$). Many parts are complex in the nature of the layup and very labour intensive. This work is done by highly skilled technicians. They manufacture components for defence, aviation, surveillance and medical industries.

The tooling also has mould heating which is made possible by a cavity that is cut into the back of the tool to allow oil to flow through it, providing the heating media. The process is very reliable as the parts are laid up during the day and allowed to cycle through the cure during the night. Mark often presents at composite seminars, relating to out of autoclave composite moulding, for the South West Composite Gateway.

Takeaway Learnings:

Seeing the skill level of the technicians who made the tooling as well as those who performed the layups, the Fellow is convinced that a level of industry commitment in Victoria and Australia needs to improve to remain competitive in the current market.

Organisation: Faculty of Engineering Materials, 26 September 2013

Location: Plymouth University, Plymouth, UK

Contact: Dr John Summerscales – Associate Professor, Research Coordinator for the School of Marine Science and Engineering

The Fellow was able to visit Plymouth University after an invitation from Dr John Summerscales who conducted a presentation at the LCA seminar. Dr Summerscales heads the Faculty of Engineering Materials. Plymouth University's composite engineering facility enables engineering graduates to learn both theoretical and practical aspects of composite design, analysis and processing. Many of the students are employed by the composite industry to find real-time solutions to industry problems.

An example of some of the work the graduates are undertaking is replacing the sprayed gelcoat coating on LRTM mould faces with an injected gelcoat coating. The benefits of this will be reduced VOCs created while applying the gelcoat to the mould faces. The process has been tried before in the USA but at a time the effects of shear and viscosity on the cure may not have been fully understood. With the advancements in LRTM, there is a better understanding of how pressure can effect a curing resin.

The difference to the existing practice is that the part is shot first. The gelcoat is replaced with a shim situated against the mould. The shim is removed after the part has cured. The part is put back into the mould. The gelcoat is then pumped in to fill the cavity that was left after the shim was removed. Although they are still in the testing phase of development, the Fellow can see that development in the RTM pump system will be the next phase of development so that it becomes a one shot solution.

Takeaway Learnings:

The graduates are paired with industry to work on real-time solutions which the Fellow believes develop a more holistic and up-to-date approach to understanding the engineering industry. Graduates are also encouraged to be more hands-on in relation to their projects, with access to a modern equipped workshop. One of the students (an international student from Greece) recently built a track bike for velodrome racing that was stiffer in its construction without adding extra weight. He has since been contracted to build the bikes for the British track cycling team.

Organisation: Composite Integration, 27 September 2013

Location: Salt Ash, Plymouth, UK

Contact: Stephen Leonard Williams – Managing Director

This company manufactures LRTM equipment of their own design and composite tooling. They assist their customers by developing the processes, building the tooling for them, provide training in mould construction and equipment operation. They also have agents for their equipment in Australia through Lavender Composites. Their largest customer is Princess Yachts where they assist with day-to-day operations with real-time connectivity to their PCs and boardroom.

The Fellow was able to witness layup preparations for a 50 metre hull and deck. The company has developed a manifold system that allows remote control of resin through the feed lines. This also negates the need for premixing resin and adding to a feed container. Premixing can introduce air into the laminate and have differential catalyst rates. The new manifold is connected to the RTM pump which is a closed loop system and avoids these concerns. It can also supply both moulds simultaneously.

Takeaway Learnings:

The Company is trialling new methodologies and driving innovation. An example of this is an aluminium coating that they are trialling to replace the tooling gelcoat. It may be used as a heat sink to take exothermic heat away from the laminate or a heat exchanger providing an avenue to improve heat distribution during the post cure. They also believe in an engineered solution will better serve their customers. They achieve this with CAD and flow analysis software. They also developed their own version of a RTM pump (Ciject) which looks as though it has been engineered. Their website has many comprehensive videos demonstrating moulding manufacture and their process aligned with projects done with their customers.

Image 5: This shows a half the top view of an LRTM mould, showing a catchpot centre right and pressure valve centre left.

Image 6: This is looking at the front of the cutaway. The countermould has been lifted to show the seals (blue) which separate clamp vacuum and the part cavity. The holes in the bottom mould facilitate mould heating. The catchpot location can be seen fixed flush with the bottom of the countermould.

Image 7: This shows the beginning of how the heating coil is fixed to the back of the mould face.

Image 8: This shows a mould surface made with resin and aluminium powder to replace the traditional tooling gelcoat. Its purpose is to distribute heat more uniformly.

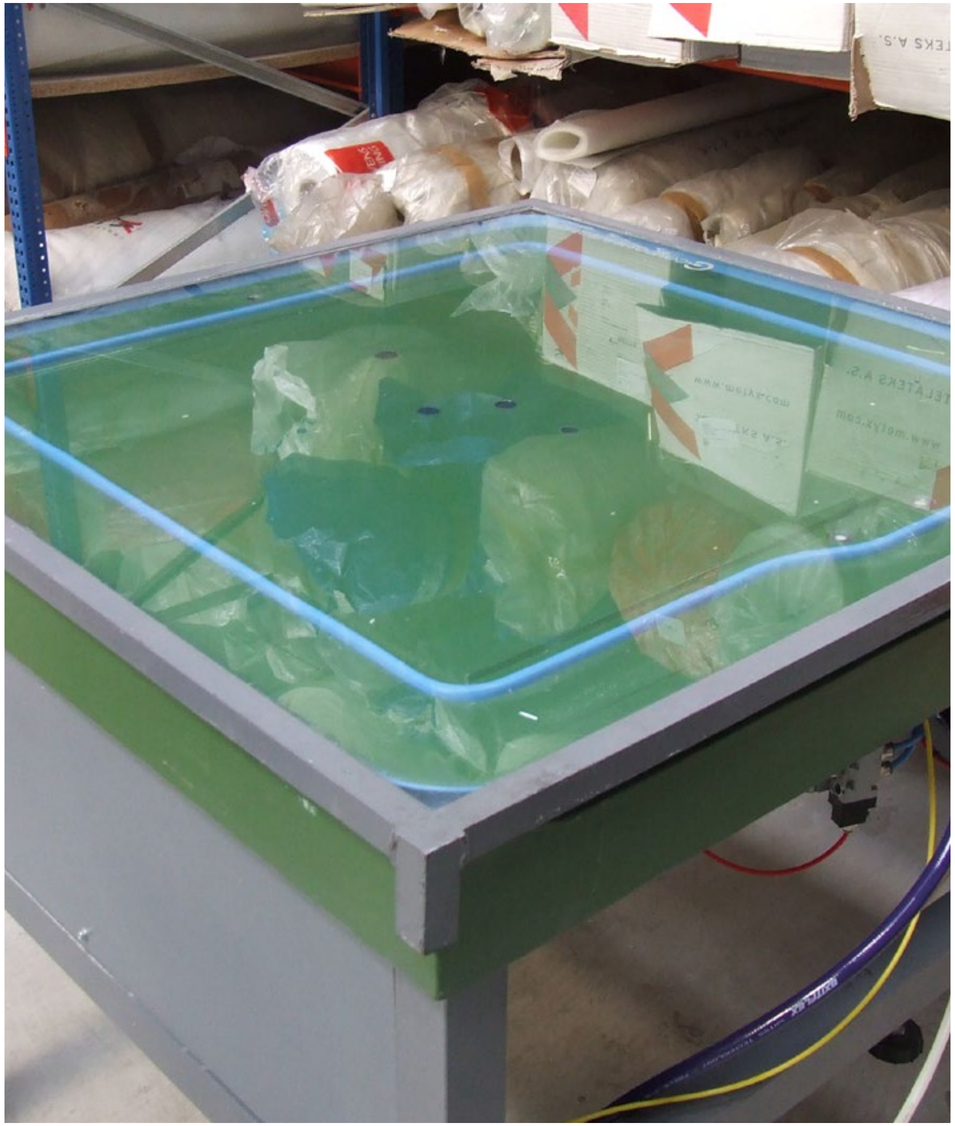


Image 9: This shows a full mould setup for trial resin flow through different reinforcements. The glass top provides vision of how the laminate performs.

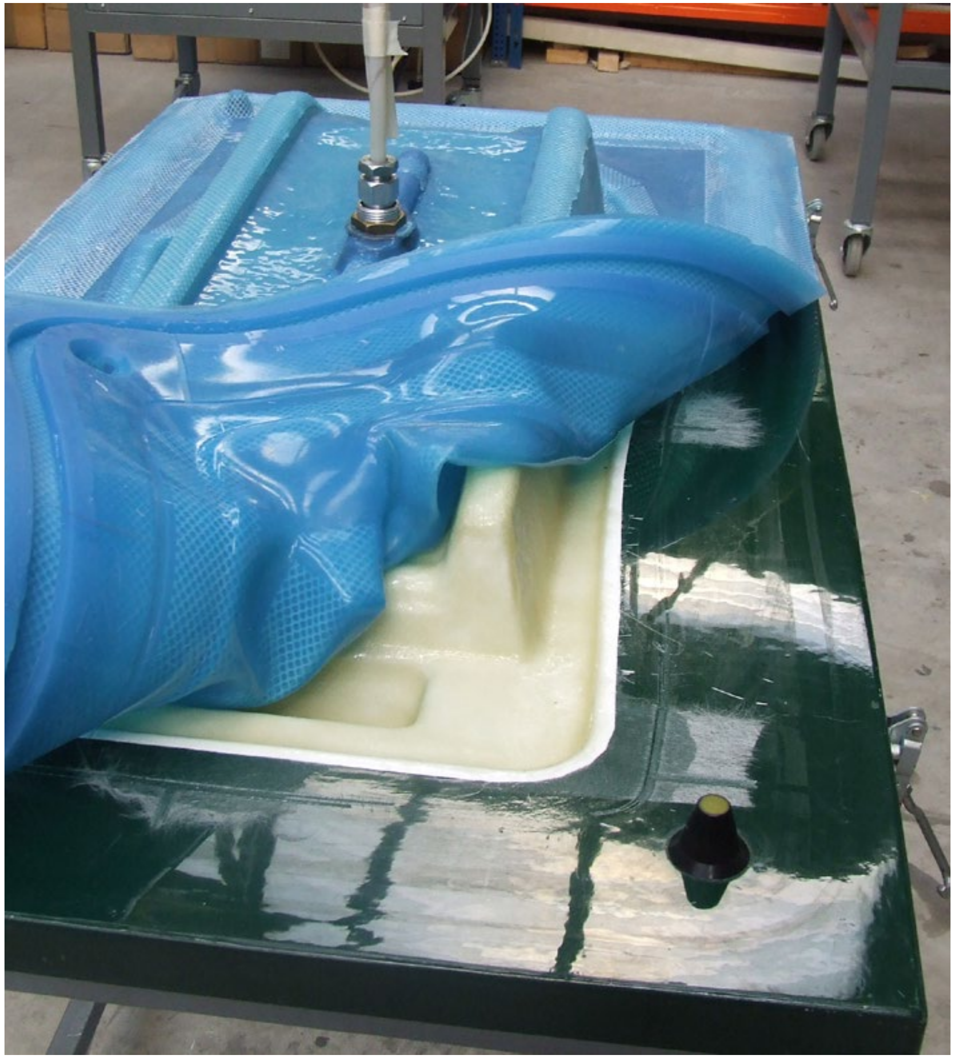


Image 10: This shows a silicon bag that would replace bagging film in situ over part and mould.

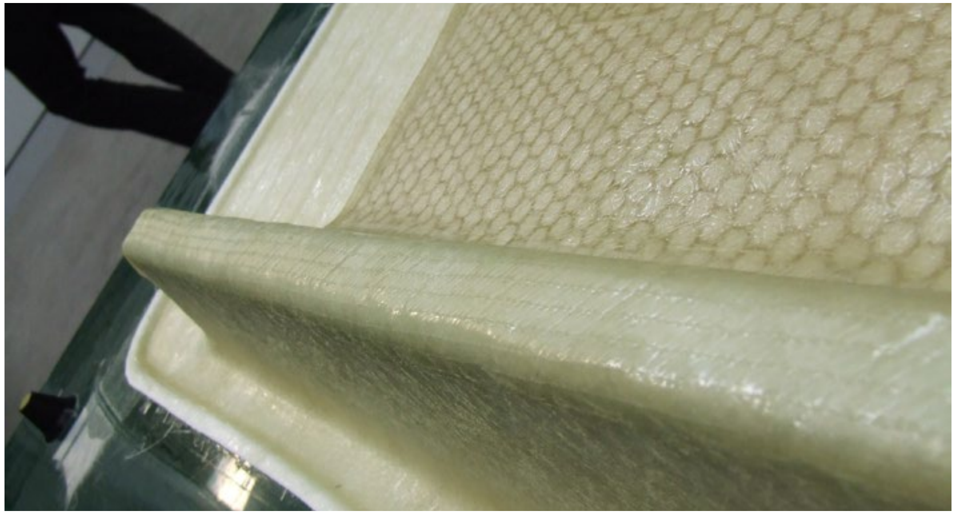


Image 11a and 11b: Image (above) shows a comparison between a finished LRTM made part to a resin infused part (below).

Image 12: Shows cork used as a core material

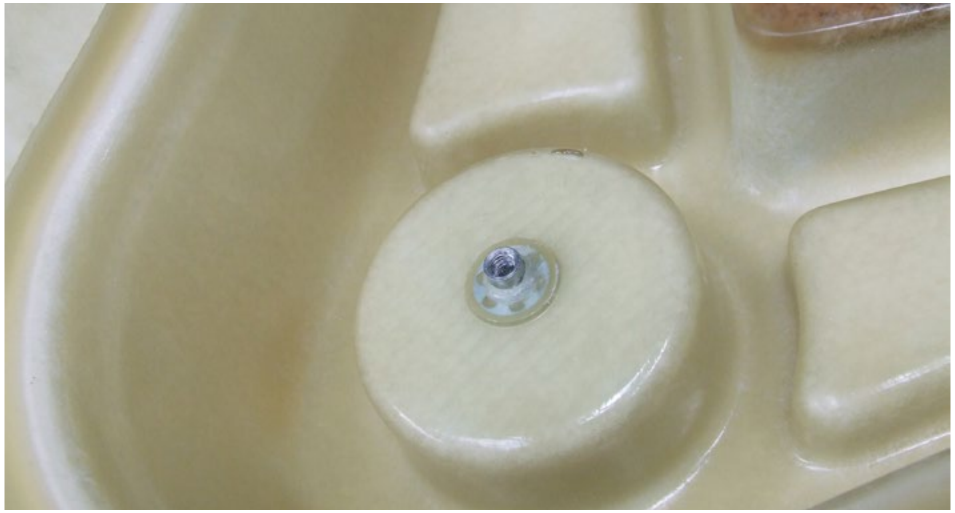


Image 13a: Shows metal thread insert that was moulded into the laminate during infusion.

Image 13b: Shows a fastener applied to the metal thread insert after part is released.

The International Experience – United States of America

Organisation: Southern Maine Community College, 1 October 2013

Location: Mid-coast Campus Brunswick, Maine, USA

Contact: Andrew Schoenberg – Director, Composites Engineering and Research Laboratory (CERL)

The Composites Engineering and Research Lab (CERL) supports composites industry research.

The lab of 30,000ft^2 houses a significant assortment of testing equipment that supports all types of testing and analysis which is fully funded by industry through donations and research alliances with industry. The courses CERL run prepare operators and technicians for work in many of the local composite manufacturing companies. Those graduates then have an option to undertake further study toward an Associate Science Degree, working again with local industry on real-time solutions as a basis for study. Further study toward a Bachelor of Science in Industrial Engineering or Technical Management also provides a unique challenge. The students also assist in developing training aids from concepts the local defence corps provide, using lightweight materials.

Along with all the testing equipment is a manufacturing workshop that is well laid out boosting a 5 axis CNC machine centre, heated spray booth, extensive woodshop and a dedicated trimming booth with the usual lecture areas housed in the workshop. CERL also has several TCM machines.

CERL assisted in testing samples that came from the initial development of the process which was developed by the Kenway Corporation. The reason why this process may be considered ground breaking is that laminates have been restricted by the thickness that can be achieved in a single layup due to the exotherm that is generated when too much resin gets so hot that it can damage the fibre as well as making the resin component brittle. Short of using metal tooling, there are not many options for using cold curing resin systems.

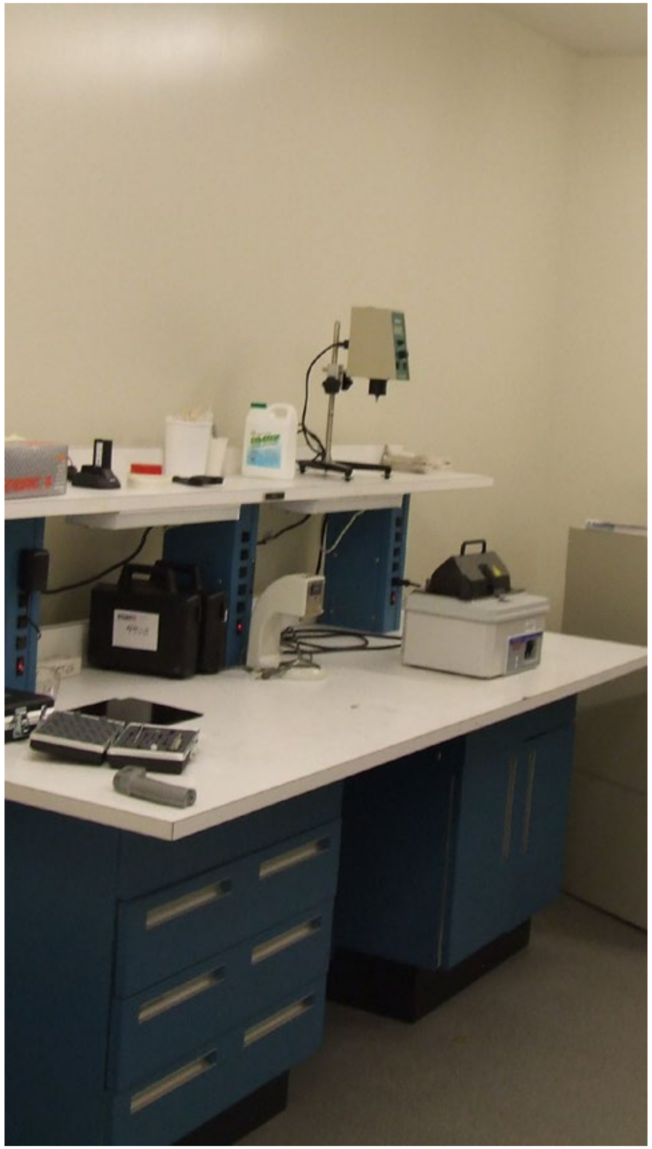
The TCM mould top essentially has the ability to cool thick laminates as the resin start to exotherm through the cure and then reverse the cooling cycle to a heating cycle to post cure the laminate. Previously laminates could be laid up to approximately 10mm before too much heat was generated. With this process, laminates up to 150mm can be controlled through the cure.

Takeaway Learnings:

Anyone visiting would be envious of the facility itself. The range of equipment that supports composite industry learning right across the board (trade through to PhD levels) is truly unique. There are no barriers to students working on real-time problems as they frequently engage with industry.

Image 14: Shows a TCM (Temperature Controlled Machine) machine which is able to control the exotherm of an infused laminate by altering temperature at different areas of the laminate. These laminates are very thick, up to 50mm in one layup.

Image 15: Shows a communal classroom/workshop.



Images 16a, 16b, 16c: Show a range of scientific laboratory equipment for studying laminate and resin structures

Image 17: Shows a fully ventilated wet layup room.

Image 18: Shows a 5 axis machine centre.

Organisation: Kenway Corporation, 2 October 2013

Location: Augusta, Maine, USA

Contacts: Ian D. Kopp – President/CEO and Alexander Thibodeau – Director of Business Development

The Kenway Corporation used to be heavily involved in boat building, starting out building timber boats for the local market. They are very proud of their achievement as the walls of the board room are adorned with advertisements of boats they built over the years. They were one of the first boatbuilders to convert to fibreglass back in the late 60's.

Although the focus now is on composites for mainly industrial applications, they still build the custom styled boats when the need arises. It was the industrial applications that got them thinking of ways to speed up the laminating process. As stated before, limited by 10mm layup at a time, you would have to wait until the exotherm cycles through before laying up the next 10mm. With higher wages than that of Asia, they had to come up with a way to reduce the cycle time. TCM was about to be born.

The premise behind the mould table is that a fluid gallery directly under the mould surface helps channel away hot coolant with the aid of a temperature controlled pump. The fluid is chilled down to 0°Celcius until the peak of the exotherm starts to drop. The fluid is then diverted through a heat exchanger to heat the fluid which in turn raises the temperature of the mould and laminate to a nominated post curing temperature. While to pump unit is the easy part of the process, a lot of work was done to find the right temperature to reverse the heating cycle. The competitive advantage in the licensed information relates to the application of the resin – catalyst, thickness and curing temperatures that a laminate will require to control its exothermic reaction.

From a tooling perspective, the process can be used to build tooling that is possibly lighter in section and dimensionally more stable as the cure of the mould is more complete. The cure enables the higher shear resistance (approximately 20 – 25% to be achieved. The downside may be that a different high temperature resin may need to be used increasing the cost in that respect.

While the pump has been fully developed now, they outsource the construction of the pumps to Advantage Engineering. Development of the TCM system has become the premise behind the way they engineer their composite components. Using CAD and FEA software, they can offer their clients a complete engineered solution. This methodology seems to be a way of keeping costs in check.

Image 19a: Shows 10m x 5m layup table - the temperature control unit sits under the layup table centre right.

Image 19b: Shows the control panel for the temperature control unit which is manually controlled. There are units available that can be linked to semi automatic closed loop systems.

Organisation: JEC Americas, 2 – 4 October 2013

Location: Convention Centre, Boston, Massachusetts, USA

Contacts: Silvia Popa - Account Manager for Australia & New Zealand, South Asia

This is a trade expo, showing materials, processes, machining applications, tooling, prototyping, testing and validation to do with composites. The space covered would be twice that of the Exhibition Centre in Melbourne but equates to about a third of the event held in Paris, France. The JEC is the largest composite industry organisation in Europe, based in Paris.

JEC runs expos in Paris, Singapore and Boston. It also runs smaller conferences and seminars in conjunction with other composite stakeholder to bring the composite community together. During these expos, informative seminars are run on specific aspects of composite use, manufacture or innovation as composites now affect many different industry sectors. Known as the Innovative Composites Summit (I.C.S.), these seminars encourage industry specialists and professionals to introduce their new technologies, innovations and design concepts.

Image 20: The Boston Convention Centre (approx. the size of our Exhibition Building in Melbourne).

The content of the seminars expressed a huge emphasis on carbon fibre use, design, innovation into new industry sectors, development of resin interface and what place thermoplastic materials will play in future fibre development.

During the course of this expo the two most significant presentations from my perspective, pertaining to this Fellowship, were:

'Modern Composite Aircraft Development' - John O'Connor, Siemens PLM

The premise behind O'Connor's presentation was the use of one of their design suites called Fibresim for optimizing design and analysis in a seamless operation to reduce the time getting product into production with less error in development. This tool can work between most high-end CAD and PLM packages. O'Connor also commented on the idea that this methodology can be applied to the development of any composite part and is not just dedicated to the aircraft industry. Analysis and design can also be applied to the automation of processes that may currently be done by hand.

'CNC machining of composites' – Benedikt Brocks, Sauer Ultrasonics (a division of DMG Moriseiki)

Machining composite parts with CNC is not new but the presentation put an innovative spin on where machining composites might go with the aid of ultrasonics acting on the cutting tool. As the tool moves through the cutting path, the spindle oscillates up and down on the Z axis up to 0.4 mm to give a cleaner cut with no fiber breakout. Because there is less pressure on the cutter, higher machining speeds can be achieved. The look of the cut surface resembles a finished surface.

If a composite surface is damaged and data from the layup schedule can be programmed into the tool path, the tool can prepare the surface for repair with a level of accuracy that could never be achieved by hand.

Future developments for the process will see a mobile version of the machine available in two years that will be able to be setup on a wing of an aircraft. It will be able to scan the surface where the damage has occurred, match that data to the layup schedule. Then setup a cutter path to create a scarfed surface, cutting layer by layer. Data is also sent to a ply cutting machine to accurately cut the plies required for the repair.

Organisation: JMH Technologies

Location: Convention Centre, Boston, Massachusetts, USA

Contact: John Moore – Managing Director

The Fellow was able to meet with Mr John Moore at the JEC expo, which negated a trip to Michigan where he is based. Moore has been at the forefront of tool development in LRTM. Moore has developed a mould construction process and has also engineered his own machines, he runs a blog on LRTM and has posted many tutorials on building LRTM composite tooling, and he provides training to the users of his equipment and runs training courses for potential clients.

The Fellow was able to discuss details of some moulds that he was building with him. These moulds have return flanges (see figure A) that require inserts to support the flange as it is being formed. The inserts need to be released from the mould before the part can be released from the mould as the part is locked into the mould because of its shape.

The design of how this is achieved becomes important as if these inserts move while the part is being shot, then the reinforcement can be pinched and not wet out sufficiently and also changes the flow characteristics of the resin in relation to the vacuum ports within the mould.

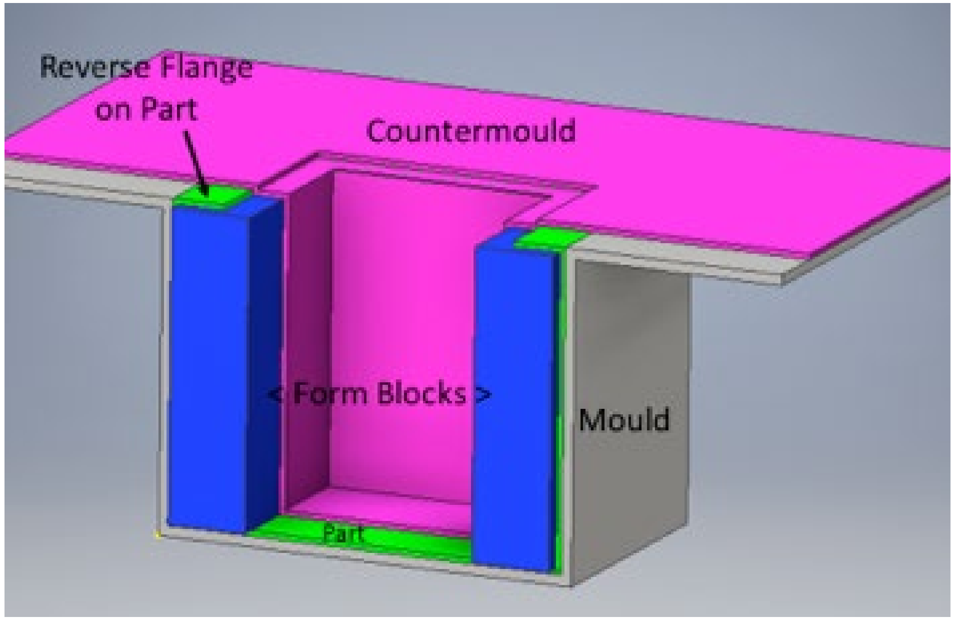


Image 21: Shows a cutaway of an LRTM mould with a Part with a Return Flange. It also shows the arrangement of Form Blocks and Countermould without the seal detail.

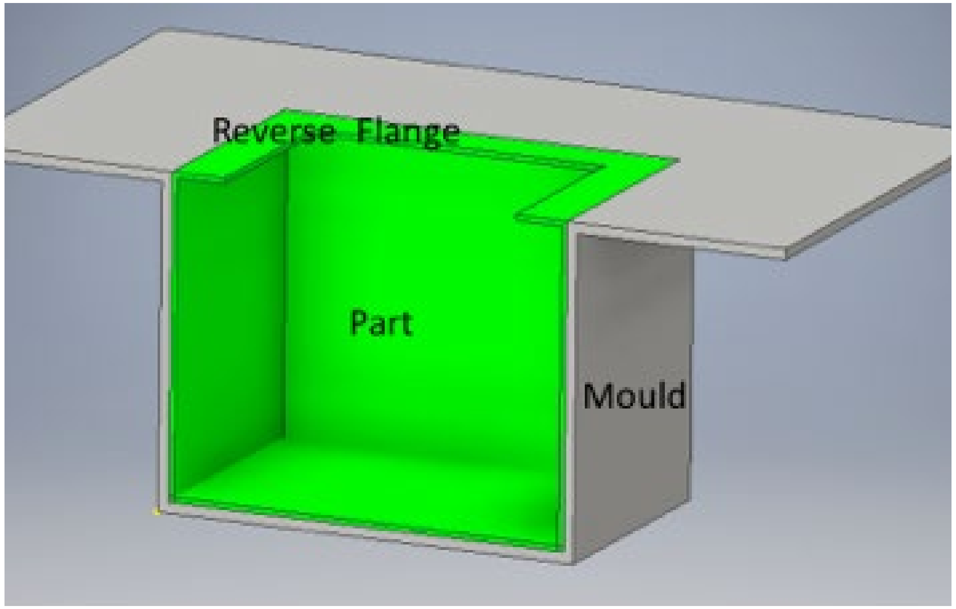


Image 22: Shows a cutaway of the Part in better detail after removing the Countermould and Form Blocks.

Generally the flange detail would be in the opposite direction and would normally be trimmed off. It was also difficult to do reverse flanges as it is difficult to remove air voids.

Other inserts for undercuts in the parts also require removable inserts or form blocks. These need to seal on the mould face and design to be released so that they are removed after the part has been released from the mould.

Often the problem in getting your head around relatively new processes is that most people are encouraged to use a small simple shapes so they develop confidence in the process without investing a lot of time and money. With the amount of good information that is available from the pioneers of the process, it is possible to start the journey using more complex examples, providing that the technician has the basic skills to build a mould. Some things need to be taken into consideration.

» The Clamping Force: Access whether sufficient force to hold the two mould halves can be done with vacuum or by mechanical means.

» Position of Resin Inlet and Vacuum Outlet: Position of ports are determined by flow characteristics of resin /reinforcement configuration, shape of the tool's cavity and position of undercuts/inserts. Usually positioned in the centre of the flow part and on the periphery of the cavity.

» Gelcoat requirement: Standard gelcoats can be applied by hand but generally sprayed. In a production sense, the gelcoat is formulated to gel with a target time in mind. Mould heating can reduce time before reinforcement loading.

» Post trimming requirement: This is determined by the intricacy of the part and mechanical load that may be imparted onto the finished part. Some part can be finished as they are pulled from the mould, ready to use.

» Multiple cavity mould or family mould: These configurations are for a cost effective way of produce multiple parts per shot and for smaller parts for the same assemble.

» Number of moulds to countermoulds: Usually deemed by the size of the mould. Loading and infusion time may also be considered but usually 4 moulds to 1 countermould.

Image 23: John Moore (foreground) discussing the merits of his RTM machine with a client.

Organisation: ERFT Composites – Engineering Research & Flow Technology

Location: Convention Centre, Boston, Massachusetts, USA

Contact: Dr. Francois Trochu

An innovation to the LRTM process was on show for the first time at JEC. The process had recently been patented as “Polyflex”. The reason for the development of the process was to alleviate the resin sink that occurs when laminating woven cloths.

This defect is not really a defect but usually indicates a site where fibres have displaced very slightly but enough to allow an increase in resin that can shrink to cause surface voids at the overlap or underlap of the woven cloth.

The process adds a layer of silicon/elastomer to the inside of the “B” mould surface. The dry material is applied to the mould, the “B” mould is then sealed up on the “A” mould. Vacuum is then applied to create the clamp. The resin is injected until it reaches the vacuum port and locked off, compressed air is then introduced between the layer of silicon and the “B” mould to approximately 1 bar, consolidating the fiber/resin matrix and eliminating the sink marks.

The company that developed the process mainly produces testing equipment that can verify process control. They built a test rig to demonstrate the process which produced samples with excellent surface qualities.

Organisation: Sinoma Science & Technology

Location: Convention Centre, Boston, Massachusetts, USA

Contact: Roger Wu – Market Development Manager

Sinoma 3d weaves – Exhibiting a glass cloth that has been woven in x, y & z axis. These have been available in Australia, distributed by ATL on behalf of Parabeam Fabrics. The Fellow was hoping to visit their factory in the Netherlands but an unforeseen event prevented the opportunity. Currently these fibre arrangements are used in the walls of high speed trains in Europe.

However, Sinoma, a Chinese company, had a representative at the show who believed that their product was superior to that of Parabeam’s, as the fibers are pre-stressed in both X, Y and Z directions.

The cloth has great potential in tooling either as a direct reinforcement or an outer surface layer that can be turned into a water jacket to allow fluid movement for heating and/or cooling. This has been common practice in larger tools.

Image 24a: Shows a dense weave and a complex weave pattern.

Image 24b: Shows the vertical Z axis fibres.

Organisation: A & P Technology

Location: Convention Centre, Boston, Massachusetts, USA

Contact: Lori Kramer - Sales Representative

This company produces braided fiber reinforcements. These fibers are becoming very popular in closed moulding. Similar to what is done with hair, fiber rovings are interlaced to form a sock or tube. Why laminates made with braided fibers are becoming more common place is the angle that the fibers become arranged as they are fitted to the form, whether this is a shaped core or a form that is removed after the cure to form a hollow component.

Because the braided sock/tube is made to a certain sized diameter, it has to be twisted and stretched to make it sit on the form. When the tube is made up of multiple layers of braided fiber is difficult to align to a particular orientation. So getting consistent performance from components is sometimes difficult. But braiding directing onto a form with a machine that also controls sizing or surface placement will give much more predictive properties.

The best example that can be shown without infringing any proprietary information is a moulded gear that is part of a high speed sorting machine used at the American Postal Service. The Fellow was able to see the machine where the gear was used. Apparently the gear spins at 12,000rpm within a planetary gear spinning at 2400rpm. It too is also made with braided reinforcements. The gears that they replaced were driven by a 40hp electric motor and required regular maintenance. The new system requires a 10hp electric motor with approximately 20% more throughput and has paid for itself with the reduction in maintenance costs and energy requirements.

Image 25: Shows a gear that has been moulded with braided carbon fibre, with the bottom of the image showing the lay-flat fibre sock.

Organisation: Tibtech Innovations

Location: Convention Centre, Boston, Massachusetts, USA

Contact: Guillaume Tiberghien – President

This company produces flexible heating solutions. Made from insulated resistance wire and arranged to allow the heat it produces to uniformly transfer to the surface it is attached to. These can be laminated into the mould to provide mould heating. The elements can also be put into silicon bagging to assist the cure or post curing from the top of the laminate.

However this is not as efficient as the in mould solution as the heat will rise. When thinking about in mould temperature control it is always important to select tooling resins that have a higher maximum working temperature to that of the resin used in the part. For optimum temperature control, thermocouples can also be moulded into the tooling.

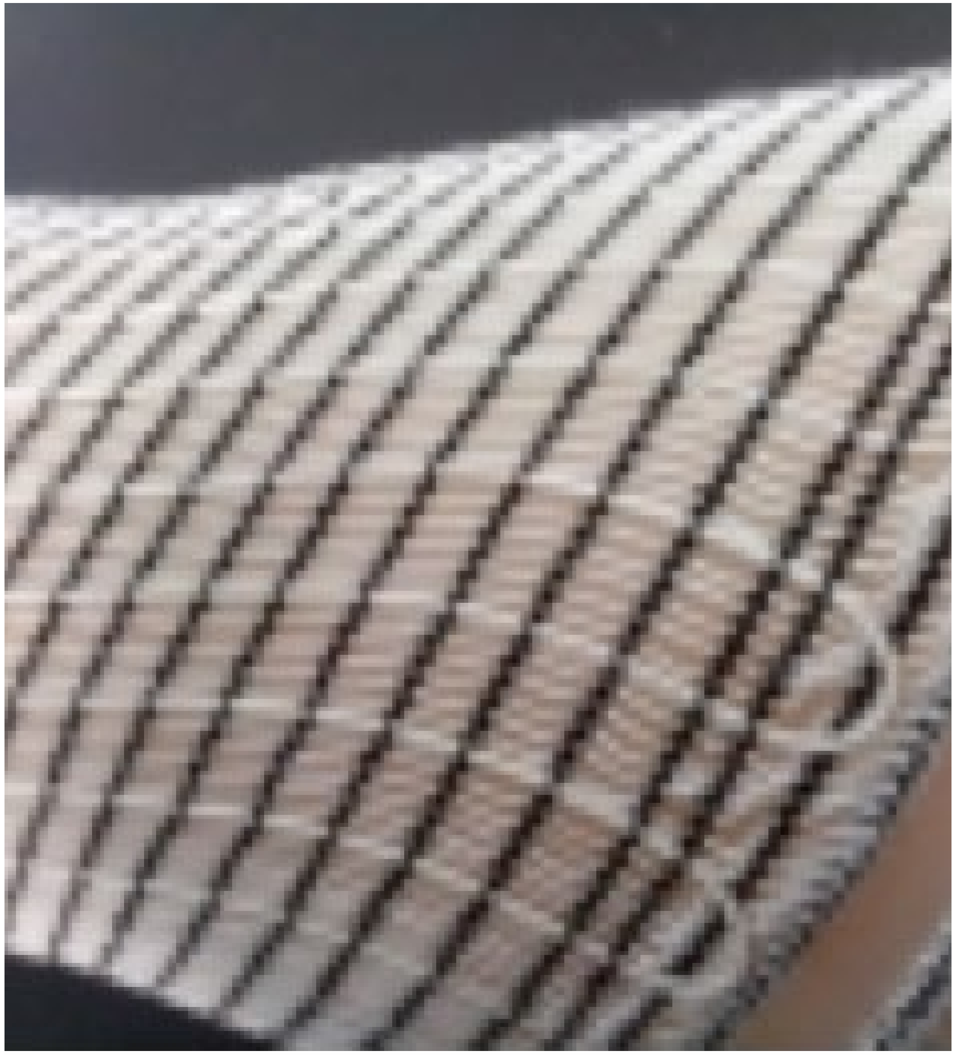


Image 26: Shows a flexible fabric heating element which can be laminated into the mould to provide mould heating. Previously only silicon blankets were available to do this task (image courtesy of Tibtech Innovations)

Organisation: Composite Fabrics of America

Location: Convention Centre, Boston, Massachusetts, USA

Contact: Rob Gray Jr. – Sales Director

The company produce a number of woven cloths. The unique thing about their capability is that they can weave graphics into the cloth in a way that it does not reduce the tensile load capability.

They can take a "jpeg" graphic and convert it to a weaving package. The cost however is expensive due to the setup cost but the results are outstanding. It is a great way to improve a brand.

Image 27: Example of a woven cloth produced by Composite Fabrics of America.

Organisation: Closed Moulding Alliance, 8 – 10 October 2013 Advanced Materials and Closed Moulding Workshop

Location: Held at JRL Ventures – Marine Concepts Facility, Sarasota, Florida.

This was an industry sponsored event. A range of suppliers and industry specialists run approximately 20 events around the USA annually. The courses they run are from entry level processing through to advanced mould manufacturing. There are approximately 100 registered boat manufacturers in Florida, with 72 of those represented at this event. Some had taken on aspects of closed moulding into their businesses but many were still using open moulding to build their boats.

Suppliers:

» Composite One – All material suppliers, reusable silicon bagging

» Chem Trend – Release systems

» Airtech – Reinforcements, core, bagging consumables, pre-preg materials, Epoxy resin systems

» 3M Finishing systems – Demonstrating abrasives and polishes used on mould surfaces

» MVP – Resin pump and vacuum solutions

» Cass Polymers – Filled epoxy casting systems

» Vectorply – Micromesh infusion media

Industry Specialist:

» JRL Ventures – Rapid prototyping and mould building

» RTM North – LRTM tooling and process innovation

» MVP – Flex-moulding, silicon bag construction

The course started with a presentation by Sidney Lainer, Head of Design for JRL Ventures. Lainer's presentation suggests that all composite solutions should be going with a totally engineered approach, and that there is not much difference between a Boeing aircraft and luxury yacht or motor vehicle. By knowing what should go into the product provides tighter control on materials, labour, tooling and processing.

JRL Ventures are one of the leading mould producers in the USA. They have enjoyed prosperity when many companies are folding or reducing their labour capacity. They believe this has been due to the engineering process and also believe that aspects of Lean Manufacturing has enabled them to meet customer demands and deadlines.

A tour of the facility showed the level of commitment they are taking with investment in their infrastructure. Although they did not allow photographs to be taken around the facility, they were only too happy to show off their new equipment and processes. The facility was only established December 2012 to take on the bulk of the mould making that their other two facilities were struggling to keep up with and have approximately three years work ahead of them. A 20 meter mould will have a lead time of approximately seven weeks in construction of plug and mould.

They are looking to expand their CNC capability to more machines; currently they boost a machine with 5 axis capability that looks more like an overhead crane than a precision tool. Its capacity can physically cut a plug 20m long X 7m wide X 6m high. They can machine continuously 60m by shifting the base bolster. They setup foam on a plywood base which gets tied down so that it is level as well as being restrained. The gantry head then machines the foam via a CNC file created from CAD data to approximated 12mm undersize.

The bolster is then removed to a spray shop which applies a sprayable panel filler material made from polyester resin. This is the most labour intensive aspect of building the plug, as they can only build-up 4 mm of product at a time, because of the shrinkage that occurs during the cure. A 20m mould may take a week to build-up a thickness of 14mm. The spray gun used is about 3 times the size of a normal spray gun and the delivery hose is large and heavy enough to require a supporting gantry.

Once the polyester filler has cured, its back into the CNC machine to cut back to final size. It will be checked with a CMM head to verify the correct size has been machined against CAD data. Once the plug measures it then gets prepared with a release system to assist the removal of the mould when it has fully cured. The plug is then coated with tooling gelcoat, then a tie layer is applied followed by the main tooling laminate. The resin system selected will depend on how the part might be cured off. The mould will be taken off the plug.

Depending on the size and shape of the mould, the mould will require some reinforcing so it can be manipulated when laying up a part from the mould. Anything over 3m² will need support for easy of handling between operation during layup. This is usually done with a tube frame that is fabricated around the back of the mould. Once this frame has been bonded to the mould the mould face will be polished and sealed ready for the customer. This is the most labour intensive aspect of mould manufacture as it is hand finished. The only variable that will be taken into consideration during the construction of the mould will be the environment that the mould will be working in.

Lainer's opening presentation was followed by Doug Smith from RTM North (Vanastran, Canada) talking about the impact design may have on the process. When does open moulding change to closed moulding? When do you change from resin infusion to reusable silicon bagging to CCBM to LRTM to RTM? Smith has been one of the pioneers in LRTM, developing the system, equipment, fittings, seals and method.

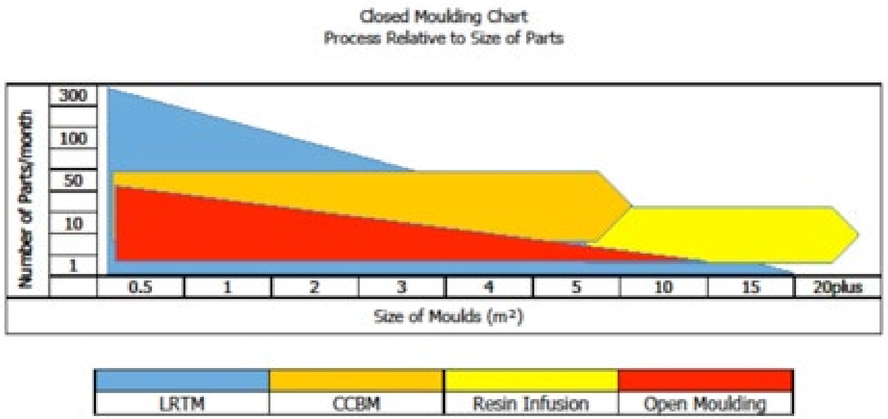


Image 28: Closed Moulding Chart (image courtesy of Closed Mould Alliance)

Mould Design Chart indicates a range of processes that could produce a quantity of parts with regard to their mould size (m^2) but does not take into account mould complexity which may reduce the monthly part quantity.

The progression to closed moulding is driven by a few factors.

» Production requirement

» Quantity of parts,

» Cost of plug, mould and part

» Complexity and size of part.

The graphic below gives an indication of the quantities required before relative processes become cost effective.

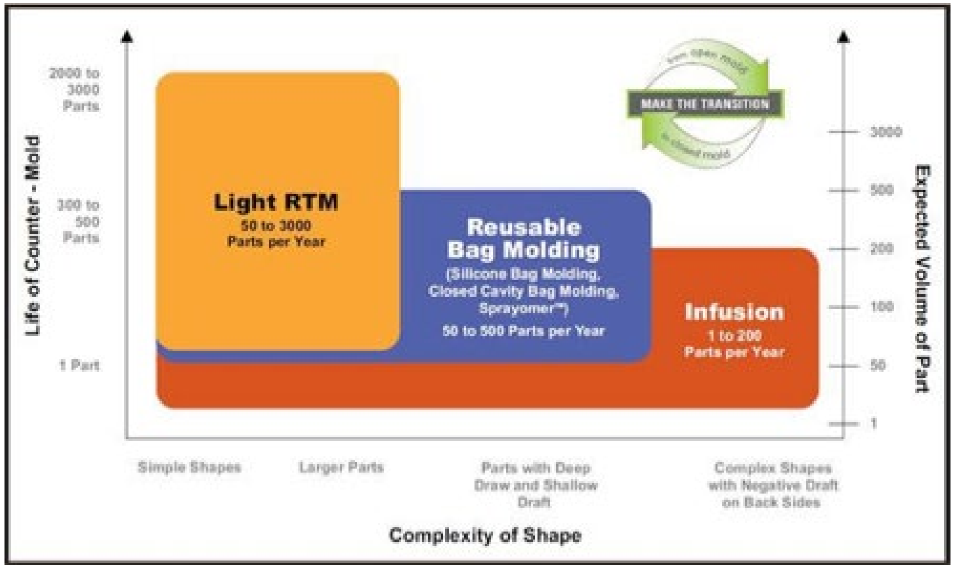


Image 29: Diagram image courtesy of Closed Mould Alliance.

The 'Road Map' below suggests that the process validation needs to be considered before converting to closed moulding.

Road Map to Closed Moulding

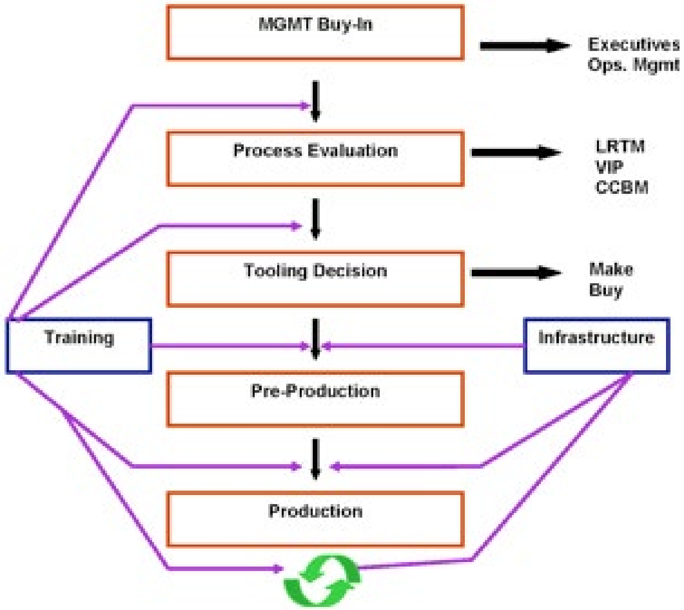


Image 30: 'Road Map to Closed Moulding' (Image courtesy of Closed Mould Alliance).

The premise behind the workshop was to demonstrate the closed moulding processes.

Release systems for LRTM are similar to those used on regular open moulding but they are subjected to more temperature extremes as they are subjected to faster cycle times and the moulds may be heated and cooled to achieve those cycle times.

A demonstration on using the Chem Trend system was performed.

They started with a coat Chemlease Mold Cleaner EZ.

Then 2 coats of Chemlease15 Sealer EZ.

Then 2 coats of Chemlease R&B EZ Release Agent.

When the parts shows sign of poor release then the release agent is reapplied.

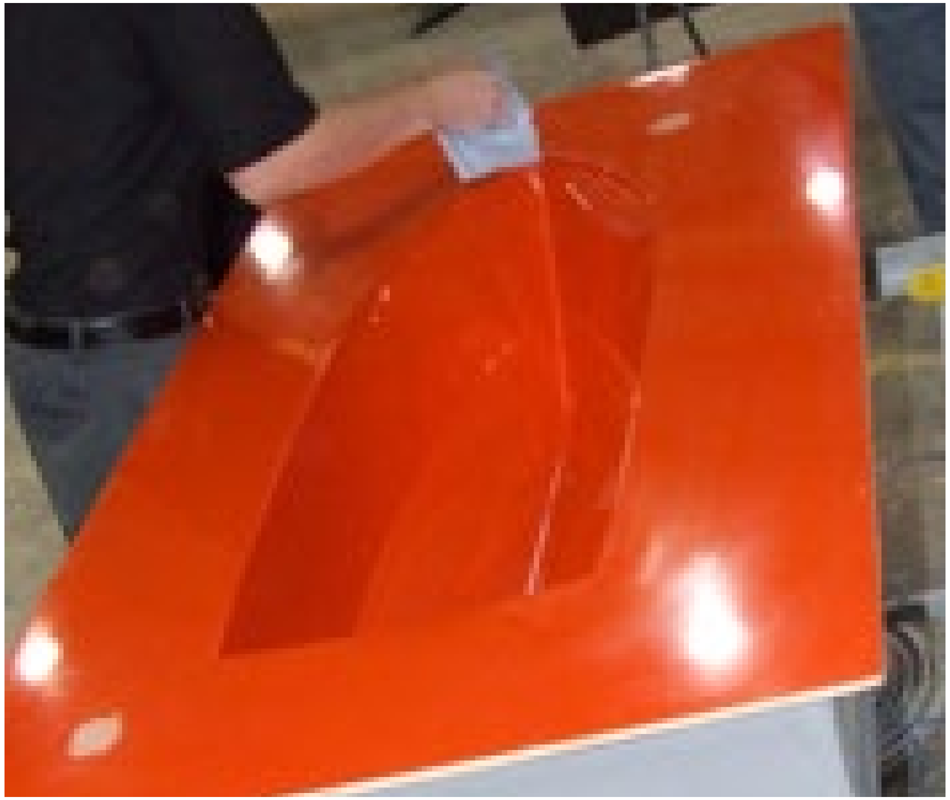


Image 30: Shows Sam Dethloff applying of the release system

Image 31 a and 31b: Shows Doug North loading the reinforcement into the mould.

The majority of the time the "A" (Main) mould would be gelcoated but demonstrations like this are sometimes difficult to be able to spray moulds because of concerns with overspray and VOC's in the immediate area. The reinforcement is a fabric designed for closed moulding. It consists of a top and bottom layer of chopped glass fibre stuck to a centre layer of polypropylene or polyester fibre. This is the media that the resin flows through to then wet-out the top and bottom layers.

The image below starts to give an indication of what process is to be used; Composite Closed Bag Moulding (CCBM). Prior to the silicon bag be placed, 4 tabs of Compoflex breather cloth are place around the placed reinforcement to provide a place for the vacuum to be generated into the cavity.

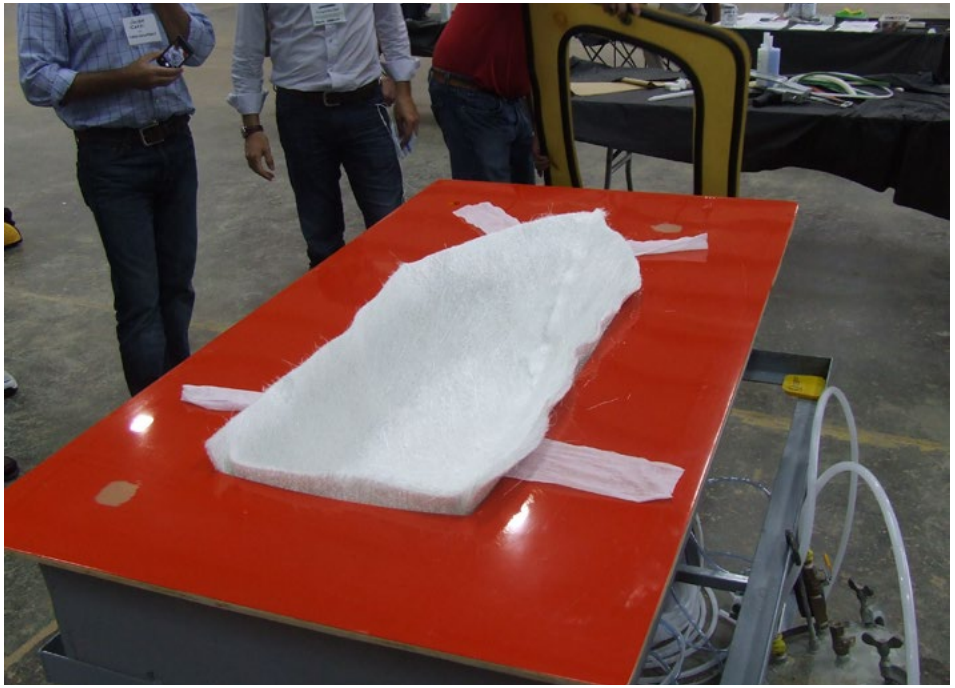


Image 32: Shows Composite Closed Bag Moulding (CCBM).

The image below shows that the silicon bag has been placed into position. Notice how the breather tabs extend beyond the edge of the bag. The silicon bag was made over the top of a previously made part

Image 33: Shows the silicon bag placed into position.

Image 34a and 34b: Shows the sealing flange being lowered onto the mould.

Image 35: Fitting the high-pressure vacuum line to create vacuum clamping (area directly under sealing flange).

Image 36: Shows a device that controls both high and low pressure vaccum through pressure regulators. Compressed air is modulated through a vacuum generator which allows complete control of pressures to provide system vacuum as well as leak detection of seals.

Image 37: Shows consolidation of reinforcement and bagging with formers so that no bridging occurs as the vacuum pressure is applied. The resin uses atmospheric pressure to push it through the reinforcement. The resin generally stops once it reaches the four tab but makes the edge of the laminate resin rich which requires minimal trimming or finishing.

Image 38: Shows the A mould has been reloaded with reinforcement. The counter-mould replaces the silicon bagging and clamping flange used in the CCBM demonstration. It is a solid one piece unit. This is LRTM. The difference between the two processes is that CCBM uses atmospheric pressure to push the resin and LRTM uses pump pressure. The cavity is separated by the thin green seal. The cavity operates under -50kPa. The larger black seal creates the seal for clamping pressure of -100kPa.

Image 39: Shows the counter-mould in place. The drum of resin is connected to the resin pump with hoses connected to the red flow control valve. The control panel counts the strokes required to fill the cavity with resin. When the stroke count has been achieved, the red valve shuts off. The grey box controls the high vacuum pressure for clamping and low vacuum pressure assisting resin flow.

Image 40: Shows that the resin has be pumped into the cavity. The resin has cured and now the part is being released from the mould.

Image 41: Time for a coffee break! A great catering concept, with the boxes microwaved for heat.

Image 42: The released part shows a high surface gloss. This is reflective of the mould surface condition. Any imperfections on the mould will show through onto the part no matter if the mould is gelcoated or not. This mould has not been gelcoated.

Image 43: Shows where the resin feeds into the reinforcement. This gets trimmed off after the part is released.

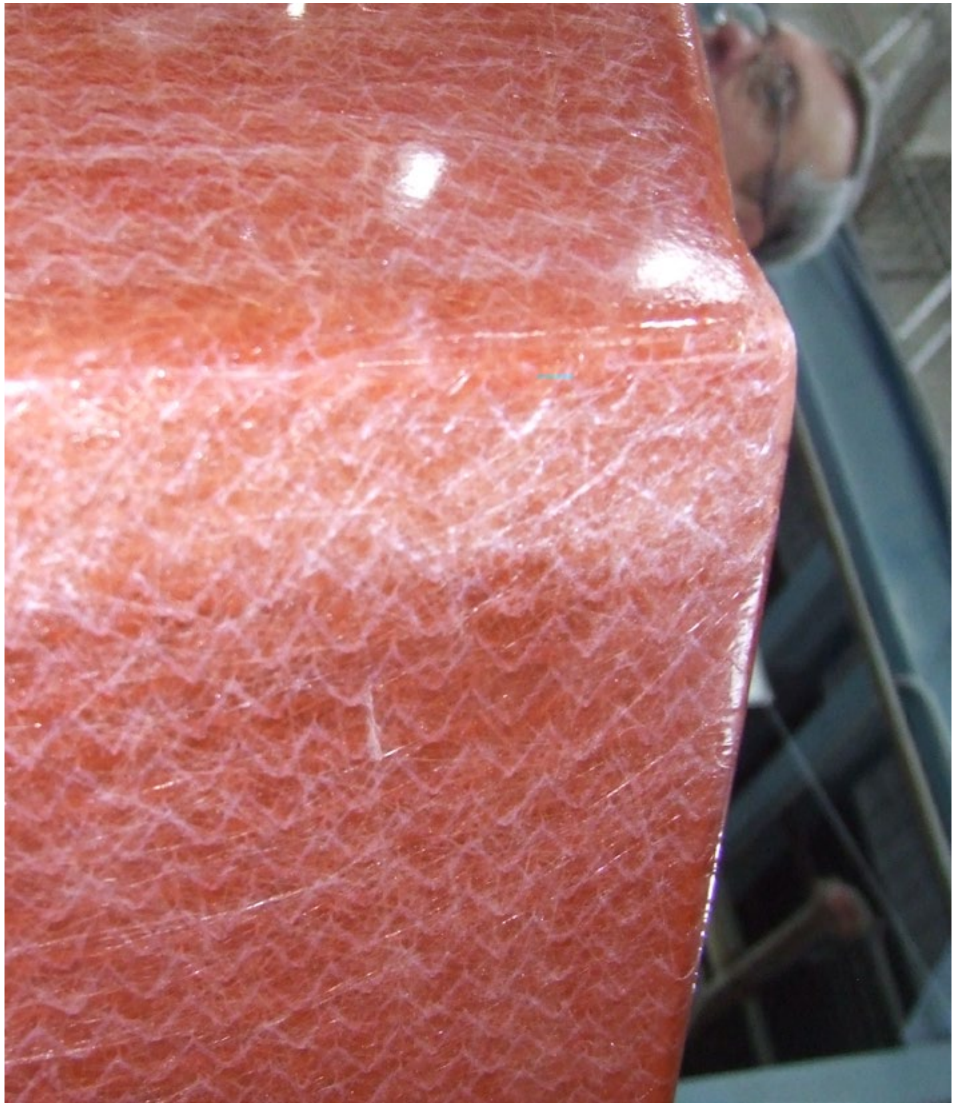


Image 44: Shows the stitching of the reinforcement that hold the reinforcement together while cutting and placement is carried out. It is usually covered by the surface gelcoat system.

Image 45: Shows a male mould with a high gloss finish that is ready to lay-up as an open mould

Image 46: The photo above is a female mould that has sheet wax applied to it to create the cavity from which the part will be formed. The part is the circular bowl and flange which sits a bit higher than the remainder of the wax sheet.

Image 47: Shows the bottom of the mould and the metal reinforcement that may be needed to overcome some of the stresses that occur while forcing the resin into the mould cavity.

Image 48: Shows the components of the cavity.

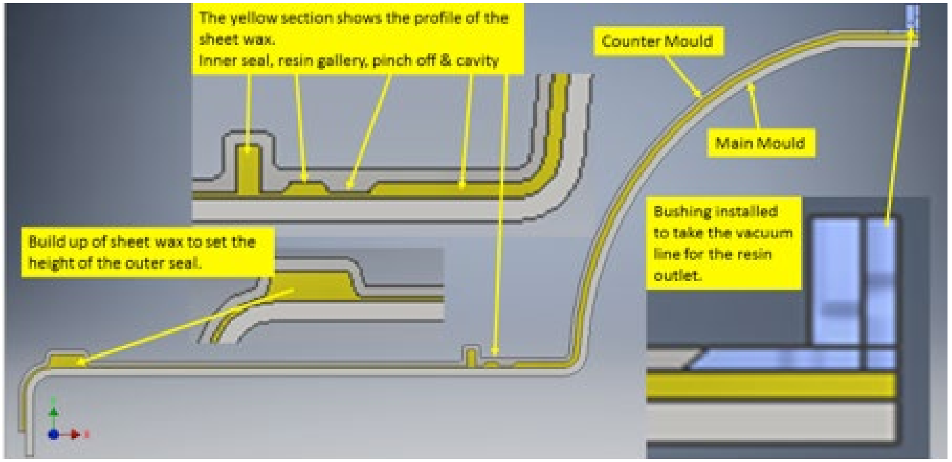


Image 49: Shows a cross sectional view through the centre of “A” mould, sheet wax arrangement and countermould.

Image 50: Shows the completed sheetwax build up with provision for inner seal and outer seal.

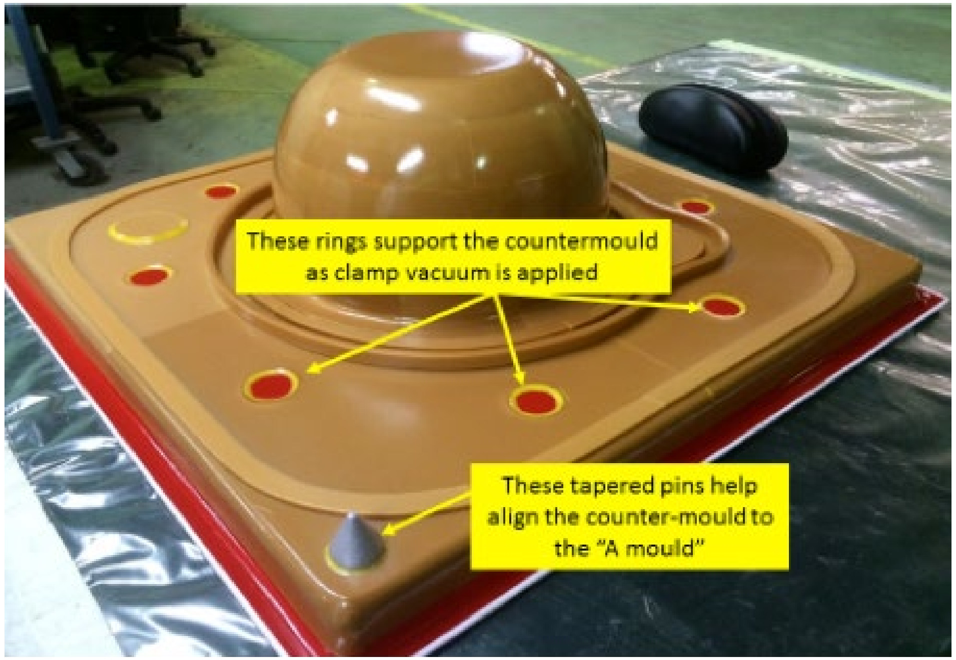


Image 51: Shows countermould clamping.

Image 52: Shows a tube coming out from the center of the bowl. This applies vacuum pressure to the sheetwax so that it does not move or lift. A PVA (Polyvinyl alcohol) release agent is applied to the surface of the wax to aid release. The surface of the mould was the gelcoated with a clear gelcoat.

Image 53: Photo above shows the completed countermould layup

Image 54: Shows the released countermould that has had the wax cleaned up. The vacuum clamp pressure port, resin inlet port and resin outlet port can clearly be defined.

Image 55: Shows the released countermould cleaned and trimmed with inner seal (green mushroom seal) and outer seal (black wing seal) installed.

There were many presentations on different resin systems for tooling. There has been much said about the merits of urethane tooling (Rentool). It is very expensive and apparently starts to break down after many hot cycles (post curing activities). On the plus side is the ability to make the tool quickly as it cures a lot faster with very low shrinkage than the other conventional tooling systems.

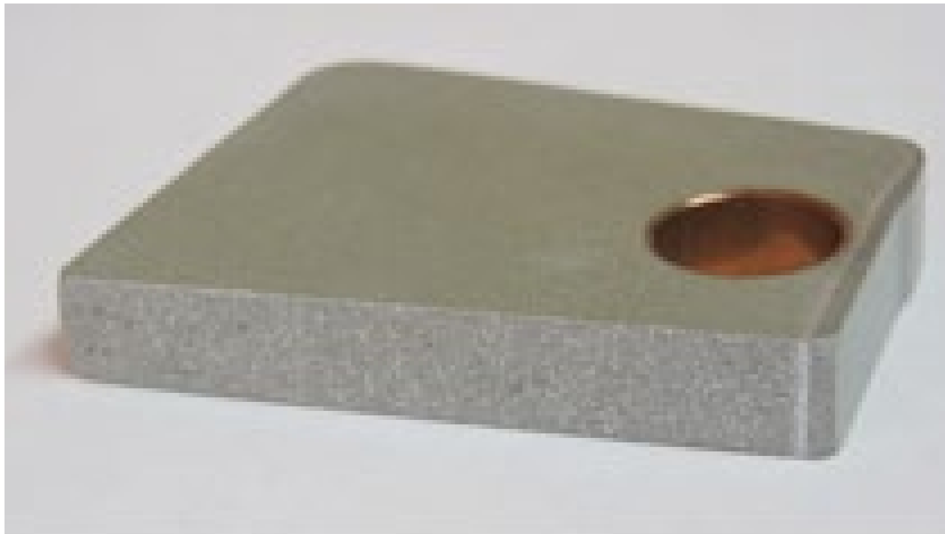
Organisation: Cass Polymers – Adtech Plastic Systems

Location: Michigan, USA

Contact: Bob Geiger – Sales Director

Cass Polymer has recently been acquired by Axson Technologies. They manufacture and supply most resin systems but are known for their cast epoxy tooling resins which are highly filled with aluminium &/or ceramic fillers to manufacture fast setting tooling that can withstand high temperatures. The tooling is very durable and cost effective. The resin is an alternative to styrene based system that are ideal for LRTM and RIM tooling.


Image 56a and 56b: Shows Ceramic Filled Epoxy Tooling Resin samples.

Images 57a and 57b: Shows Aluminium Powder Filled Epoxy Tooling samples.

The Closed Moulding Alliance event provided time for some demonstrations.

'Mould restoration and finishing', Jim Christenson for 3M surface technologies

Christenson demonstrated the latest product 3M have for restoring gelcoated surfaces whether that be a mould or gelcoated part. Using super fine abrasive papers 5000 to 9000 grit with different backings to facilitate attachment to power tools or hand held power files. These abrasive papers are finer than some cutting compounds and need to be used with a lubricant; a mix of water, wax and methylated spirits.

Christenson also showed the use of a device that reflected light off a prepared surface and at different stages he could gauge the improvement to the surface through the reflected lustre. Christenson was also able to show what happens when you over polish the surface, the gelcoat gets thinner offering less protection to the surface of the laminate.

'Mould Release Systems for Closed Moulding', Sam Dethloff for Chemtrend

Dethloff demonstrated the procedure for preparing a mould surface using a liquid release system. Most of the problems that happen to moulds occur on the edges of where the bagging material secures to the mould. Gelcoat is not usually applied in these areas so tape, overspray and excessive adhesive build-up sometimes work its way through the release agents so the mould no longer has a protective coating to stop the part laminate sticking to the mould. The worst aspect of this is when tooling gelcoat breaks away from the mould surface causing cosmetic problems and potential loss of vacuum.

The process starts with a solvent cleaner to remove the previous release system then a sealer that bonds to the mould surface. This provides a base for the remaining coats to attach to and also seals any porosity and micro-cracks that may be in the tooling gelcoat. The following coat is a liquid primer coat which becomes the permanent coat. The last coat is a semi-permanent coat that can be refreshed or removed to improve tack of sealing tapes. Applying too many coats may cause part to pre-release prematurely.

Image 58: Shows the release system labels (these are available in Australia).

Chemtrend have become one of the largest manufacturers of release agents and preparations. The company has just acquired Zyvac a company that makes permanent high temperature release systems. Chemtrend believes that development of future products can be based on some technologies that Zyvac can bring.

Developing a Silicon Bag for Closed Moulding with Corbett Leach of Composites One Corbett demonstrated how to construct a silicon bag'

The silicon resin can be applied through a cartridge dispenser or a pumping dispenser for larger bags. The silicon resin, a product from Wacker, is applied to the surface of the mould or on top of part laid up in the mould. Formed sheet wax can also be used to create the form. The resin is levelled out with a brush or spatula. The resin air cures in 10 minutes. Another layer is brushed down and reinforcement made from nylon is placed down and brushed into the second layer and allowed to dry. A third layer is applied and allowed to dry. The 3 layers form a thickness of approximately 2.5mm. Larger bags need to be thicker with possibly 2 layers of reinforcement more for the debagging aspect as the bag gets rolled or folded.

The inlets and outlets for the bag are formed over dummy forms which are a bit smaller (1 -1.5mm) than the actual size of the valve bodies so they fit in quite firmly and seal. The forms he saw were made from UHMWPE plastic. The bag can stretch up to 15% larger if a change to the layup schedule is called for.

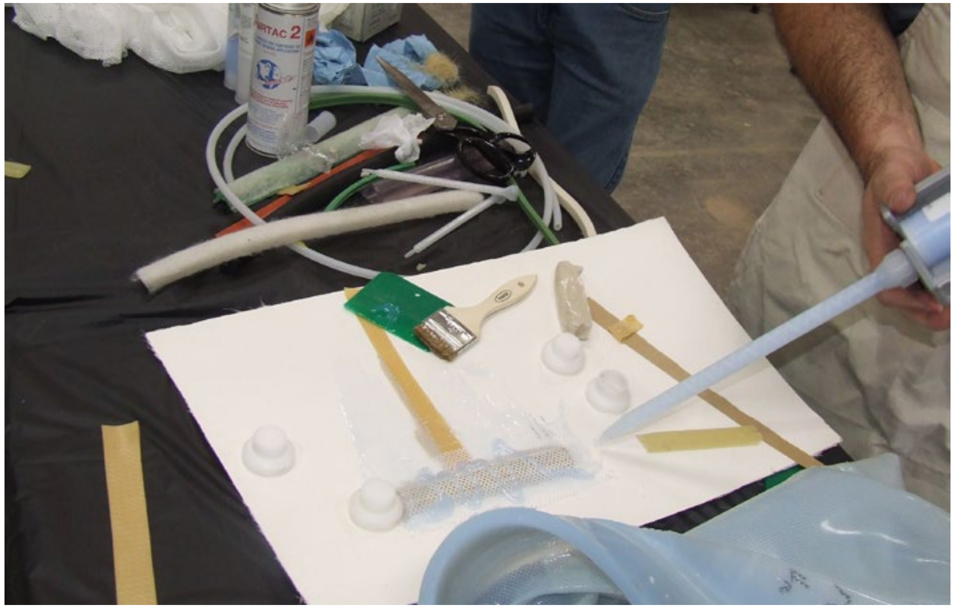


Image 59: Shows the silicon resin being applied to the forms that create the shape of the bagging. A completed bag can be seen at the bottom of the image.

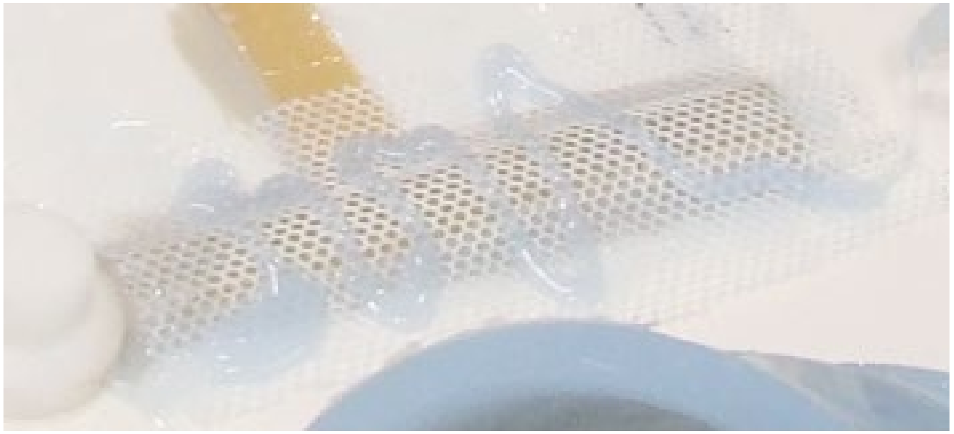


Image 60: A close-up shot shows the reinforcing mesh that holds the bagging together.

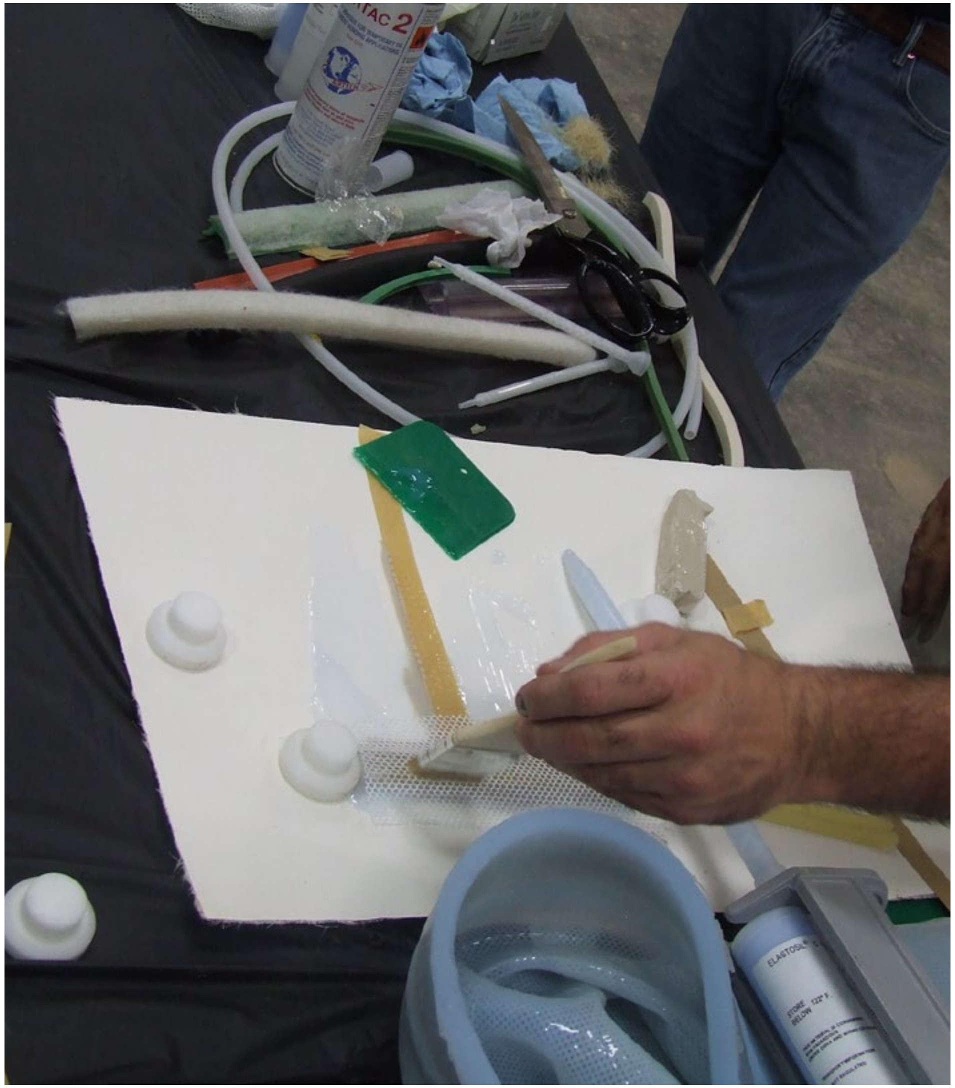


Image 61: Shows how a brush with shortened bristles is used to distribute the silicon resin through the mesh and over the forms. The silicon resin used to manufacture the bagging is available through 'Ironbark Composites' (Torquay, Victoria).

Organisation: Skagit Valley College, Marine Technology Center, 16–17 September

Location: Anacortes, Washington, USA

Contact: Mike Swietzer – Head of Department

The Marine Technology Center prepares students generally for servicing and repairing the fishing fleets that operate from the area. Their composite programs start with secondary school students by introducing them to basic layup processes; they then learn about marine engines, transmissions, electrics and electronics. In fact, they have a composite shop of a similar size to the one the Fellow has use of. These courses then articulate into degree programs but more to do with fishing fleet management. Because of its location, the Centre also provides a venue for training programmes like the event which the Fellow attended in Florida.

The Center has also assisted with laminate and process development for an America's Cup catamarans. The boat unfortunately failed in a sailing accident from which the Centre was able to assist with an engineering solution to stop further failures.

Image 62a: Shows the Skagit Valley College timber workshop

Image 62b: Shows the Skagit Valley College spray booth where their layup work is done (the booth can be heated).

Image 63a: Shows a ply cutter for cutting reinforcement fabrics

Image 63b: Shows a small handheld device for cutting spiral-flex used in resin infusion (it is a tool that the students all make).

Image 64: Shows the fleet of fishing boats which are next door to the school. The students will often work on the mechanics of these boats as a work experience opportunity.

Image 65: Shows a section of an 'America's Cup' boat hull that failed.

Takeaway Learnings:

This is a great little facility that seems to cope with the demands placed on it. However, they do not have enough trainers that have experience in composites; an underlying issue right throughout the USA. The trainers were also impressed about the MEM31112 qualification that we have in Australia. Over dinner the Fellow was able to share some of the problems that our industry has, with us concluding that the problem is not unique to just Australia. The USA has many industries where the use of composites is replacing traditional materials with little expertise to exploit the possibilities or not enough manpower to produce the components.

6. Knowledge Transfer: Applying the Outcomes

Several means of transferring the knowledge acquired by the Fellow during his Fellowship is provided below.

Firstly, a presentation of aspects of the trip that could describe the technologies that will have a probable impact on the composite industry. By providing industry with prior knowledge that may fuel innovation in the types of tooling/parts and assemblies that may not be otherwise possible. This is to be provided at the 2014 Composite Australia Annual conference and at a state briefing event also held by Composites Australia in 2014. There is also a possibility of an event with the Society of Plastic Engineers (SPE) 2014.

Secondly, develop resources that can reflect on the technologies seen and applied to the different training scenarios. This will enhance current training capabilities by offering alternative methods to current mould construction and use. This will be ongoing as materials and processes are established and used in Victoria and Australia.

Thirdly, encourage industry members in state and throughout Australia through training activities on aspects of closed moulding. By making available information relating to these technologies and their respect developers as part of apprenticeship training. The Fellow will meet with prospective employers and interested industry clients. This again will be ongoing as materials and processes are established and used in Victoria and Australia.

Finally, develop a combination of current technologies to try and reduce costs in processing. On a personal note, the Fellow was able to conceive ideas centred around materials and technologies that have not been fully developed or used to develop products in another industry sectors. Through incidental R&D trials between training programs, the Fellow will look at possibilities that can be used in production. These will be products found overseas and not necessarily available in Australia as yet.

7. Recommendations

Closed Moulding

A series of training programs need to be delivered to promote the technologies that the Fellow has seen and gathered knowledge from. This is to be done in two ways:

1. An option is bringing in overseas trainers to provide specific knowledge relating to the many avenues of closed moulding. By promoting trade events that will allow industry, material suppliers, technologists and engineers to share in their ideas and techniques.

   In the past the idea of collaboration has been a difficult concept for manufacturers to grasp as the competitor was often 'just down the road'. Now we are seeing projects setup with small to medium enterprises working together to share resources, manpower and capital expenditure. The composites industry came together just before the Fellow headed overseas, to talk about how closed moulding could be introduced to industry with a shared approach. Many businesses who have tried LRTM have not been able to get their projects off the ground due to a lack of expertise or time/money constraints.

2. To assist industry, the government could assist through innovation grants to establish a formal group of collaborators with the agenda to learn and share the how to experiences with other interested industry groups. Each member of the group would have a project in mind that could be completed over a month. The grant would cover materials, a range of equipment available, trainer and collaborators' time. Everything done could be recorded as a training resource for others coming through. The collaborators would have to be available to mentor newcomers as it is about the process and not taking work away from anyone.

Composite Engineering

There are two aspects to this which academic engineering seems to be disconnected from:

1. Academic engineering seems to be disconnected with the people who make it happen on the floor. Engineers and scientists who create and innovate materials are slow to talk to industry who will be charged with making their creations a reality. At times a research program will be left in a PhD candidate's hands which often looks at a very narrow realm of research where instead the need to get university students (engineering and scientific) to be involved in real-time learning and understanding the composites industry is required. The Fellow is sure that engineers will have a greater understanding of the challenges that industry has when design or artisan approaches fail due low degree of practical knowledge transferred by the universities.

   The Fellow was able discuss qualifications and training with two engineering students overseas. They both were partially sponsored (which helped with tuition fees) into industry product development programs. Both took pathways through their community college system (like our TAFE system) then expanded that onto engineering degrees.

2. An emphasis on providing an engineered solution to tooling, parts and components made from tooling. Explanations and technical demonstrations on CAD, CAM and CAE as applied to composite tooling and component design needs to be made available to industry. Currently, only some aspects of industry can apply CAE to their manufacturing capability.

3. The cost of the software that can be used to design, simulate and analyse composite manufacturing is quite expensive and it takes time to learn. Private training providers offer intensive training over five day periods provided you buy their software and TAFE training is limited to training against unit outcomes. TAFE could be charged with delivery of a purpose-built program using the Diploma of Engineering (Technical) as a basis for learning outcomes which are more closely aligned to the industry need. It could be funded partially by the Workforce Training Innovation Fund organised through HESG & the State Government. Again, the group needs to be able to share their experiences with others learning the “how to”.

   The options to train people from industry so that they can develop more efficient practices would deem that they may need some assistance to access the software and/or the appropriate training to develop their products. Certainly, there are design consultants who have the software but they may not have the experience with composites to justify any changes to current practices. There are a few CAD packages available that can predict the best layup schedules, cloth relief for darts and pleats. These files are converted and sent to CNC fabric cutting machines. FEA software has comprehensive fibre databases embedded in them that can provide failure and optimum stack solutions.

   The licensing cost for any or one solution (that is CAD, FEA, CAM or CAE) is very expensive depending on the level of engineering required. Examples include:

   » CAD software: CATIA, UNIGRAPHICS, SolidWorks, Composites ESA

   » FEA software: ANSYS, COMSOL, Nexus

   » CAM software: MasterCAM, DelCAM, Solid Edge, PTC CREO, ALPHACAM

   » CAE software: DASSAULT PLM, Siemens PLM.

Environmental

There were indications throughout the UK that they are being directed by Europe as to what policies relating to the recycling of composites should be followed. There is a scheme there whereby composite companies buy into and composite waste is disposed of using waste recovery technologies.

Throughout the USA, the EPA have lobbied for zero styrene emissions which many states have implemented. The USA is at the forefront of development of resin systems using alternatives to styrene. Favouring technologies that recover the fibre from waste, the east and west coast have stronger recycling policies than central or southern USA.

Options for Victoria and Australia will be challenged due to the distance between fabrication shops. The cost of retrieval of the waste material may deem it unviable to process. As the cost of short to medium length fibre goes up, companies may be forced to investigate closed moulding solutions to reduce waste.

Things to cause a change will be legislative in nature. The EPA’s changes to landfill requirements and federal government carbon tax initiatives will put further pressure on current businesses to adopt lifecycle policies and principles. There will be individual companies driven to change through direction from their overseas parent.

The Fellow believes that the use of composites needs to look at the waste stream more critically as the industry can lead the way for other industries. An organisation like Composites Australia could work with the Victorian Government to come up with forwarding policy that can assist industry. This may be adopting strategies from overseas or developing our own to suffice the unique needs of Australia being so distant from its competitors.

Training

From what the Fellow has observed, Victoria and Australia have very good and well respected training practices. As new technologies become more prolific toward industry use, the need to keep pace with those changes is paramount. The TAFE sector has been accused of poor performance when reacting to industry needs and change, usually related to funding and direction of student involvement.

In the past, people coming into the composites industry have done so by accident rather than as a conscious career choice. It will be up to the RTOs to promote the industry with secondary school students through the provision of entry level programs that offer the student a career options and direction into tertiary training either at trade level or university level.

We have the necessary ability to train the industry but certainly improvements to the speed of delivery could improve by having more trainers with industry skills ready to train. Also, getting buy-in from other states to training is performed at the same standard, state to state. Industry needs to be more up to date with how the training sector works in relation to the way training is performed in tow with the industry need which would require more input from their stakeholders during training package review.

In many states in the USA, companies have stopped selling composite materials to people without any knowledge of how to use them from a safety and environmental aspect. People are encouraged to undertake two basic modules of the Certified Composite Technician training scheme run by the AMCA. The Fellow intends to work with Composites Australia to explore whether such a scheme should be adopted in Australia.

Conclusion

In conclusion, Australia has very little expertise in mould development in general. The closed moulding scenario only exacerbates our current ability to service the composite community. There are opportunities that closed moulding offers in providing different products for more industry sectors not currently catered for. Australia is a very innovative country. We can catch up if we know what the basics are. Unfortunately, the rest of the world has a head start. The Fellow disagrees with the previous thoughts that Australia was several years behind in the technology used in composites. The truth is that, seemingly, industry is reluctant to invest in technologies that will improve production targets.

An example of this is a company the Fellow recently undertook work for; a company which has the equipment but would not release the personnel who had done training to develop a tooling strategy because they were too busy with current targets. So the length of time spent between completion of proprietary training and the first mould that is attempted needs to be within a few months, at the latest, so that knowledge retention can be maximised.

Engineering the composite laminate seemed to be an underlying message across industry in both the UK and USA. This has come about with the influence of PLM in the design of composite products and processes. Other contributing factors have been the availability of databases relating to the fibre's inherent properties being available through software from material suppliers and/or manufacturers. An example of these is Cirrus by Vectorply, a USA company that produces fibre. The basic data from this program can be applied to FEA software to better understand the failure modes of the design. Resin flow analysis software is also available when trying to predict optimum flow paths in Polyworks and soon to be available Moldflow available through Autodesk.

In Victoria, and Australia the number of engineers available with a complete working knowledge of composite design and analysis about product and processes are very low. Graduate mechanical engineers who work for composite companies take a while to understand the material and process complexities or they take the post graduate route and usually end up doing a PhD, further disconnecting design to the floor. An opportunity lies with our current training pathway to develop applied composite technical units into Diploma and Advanced Diplomas of Engineering, Graduate Certificate and Graduate Diploma of Engineering.

The Fellow intends to work further with MSA to modify existing units in these qualifications to take composites into consideration. Overall, the trip was very interesting and confirmed the Fellow's thoughts as to the importance of composites as a material in general. Concepts and ideas committed to memory have already been used in training with apprentices. The Fellow saw many examples of bespoke tooling with counter-moulds, CNC cut moulds and plugs, robotic layups of parts with collapsible mandrels.

The Fellow did experience problems in gaining access to a number companies, which was a little discouraging, even though contact and invitations were made. Taking photos was very difficult in both UK and USA, as much of what was seen were proprietary processes and thus the Fellow was referred to their websites for graphics.

The UK seems to be on an economic upsurge with the investment in research and training facilities relating to composites. Although they may be deficient in the trade training aspects of composites, they cater well for their engineering graduates.

The USA is experiencing a patriot resurgence, with many of the companies bringing products that may have been built overseas, home again. The Fellow suspects this may have been part of the reason why access to some companies was difficult. Many US employees working in the composite industry train on the job. Many of these companies do participate in CCT courses. These are theory based courses that cater to operator, technician, supervisor and instructor levels across 14 processes. However, training does occur at community colleges that offer levels of training for both technicians and engineering graduates.

Again, the Fellow appreciates the help and encouragement from all those that made this trip possible.

9. Acknowledgements

The Fellow sincerely thanks the following individuals and organisations that have generously given their time and expertise to assist, advise and guide him throughout this Fellowship program.

Awarding Body – International Specialised Skills Institute (ISS Institute)

The ISS Institute exists to foster an aspirational, skilled and smart Australia by cultivating the mastery and knowledge of talented Australians through international research Fellowships.

The International Specialised Skills Institute (ISS Institute) is proud of its heritage. The organisation was founded over 25 years ago by Sir James Gobbo AC CVO QC, former Governor of Victoria, to encourage investment in the development of Australia's specialised skills. Its international Fellowship program supports a large number of Australians and international leaders across a broad cross-section of industries to undertake applied research that will benefit economic development through vocational training, industry innovation and advancement. To date, over 350 Australian and international Fellows have undertaken Fellowships facilitated through ISS Institute. The program encourages mutual and shared learning, leadership and communities of practice.

At the heart of the ISS Institute are our individual Fellows. Under the International Applied Research Fellowship Program the Fellows travel overseas and upon their return, they are required to pass on what they have learnt by:

» Preparing a detailed report for distribution to government departments, industry and educational institutions

» Recommending improvements to accredited educational courses

» Delivering training activities including workshops, conferences and forums.

The organisation plays a pivotal role in creating value and opportunity, encouraging new thinking and early adoption of ideas and practice. By working with others, ISS Institute invests in individuals who wish to create an aspirational, skilled and smart Australia through innovation, mastery and knowledge cultivation.

For further information on ISS Institute Fellows, refer to www.issinstitute.org.au

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Fellowship Sponsor - The Higher Education and Skills Group

The Victorian Government, through the Higher Education and Skills Group (HESG) of the Department of Education and Training, is responsible for the administration and coordination of programs for the provision of training and further education, adult education and employment services in Victoria and is a valued sponsor of the ISS Institute. Phillip Bovis thanks them for providing funding for this Fellowship.

Industry

The Fellow thanks to Lawrie Chenoweth of Australian Fabricating Industries (AFI) for his continued support and encouragement as industry mentor.

Professional Associations

The Fellow thanks the Board of Composites Australia (CA) for their support, overseas contacts and introductions.

Kerryn Caulfield, CEO of Composites Australia and Industry Mentor, deserves a special mention and thanks, as does Bob Paton, CEO of Manufacturing Skills Australia for his support.

Education and Training

The Fellow thanks and appreciates the support from Ray Griffiths, retired CEO of Kangan Institute, and Bill Rees as Workplace Mentor – Kangan Institute.

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