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School of Engineering

CFRP Production: SUP Paddle

Materials and Manufacturing for Niche

Markets M6X01201

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Table of content

1	Introduction	2
1.1	Aims	2
2	Research.....	3
2.1	Health and Safety	3
2.1.1	Health and Safety Legislation.....	3
2.1.2	Personal Protection Equipment (PPE) + Health & Safety rule + Everyday Practices	3
3	Methodology.....	4
3.1	PPE, Equipment and Tools Required	4
3.2	Materials.....	4
3.3	Method	4
3.3.1	T-handle	5
3.3.2	Shaft	6
3.3.3	Blade.....	6
4	Discussion + Analysis.....	7
4.1	Fabrication Methods	7
4.1.1	Lay-ups	7
4.1.2	Fabrication Methods	7
5	Conclusions	9
6	References	9

1 Introduction

In this report the production of a stand-up paddleboard (SUP) paddle is covered by a technical analysis of the skills and methods used. An analysis of low volume composite production, for niche market applications. The production of the paddle spanned over several weeks of two-hour work sessions in the composite labs on site at UWTSD. The report looks at the different composite manufacturing techniques and methods used in the construction of the paddle and any alternative that could have been used.

1.1 Aims

The aim of this technical report is to relay the methods and techniques used during manufacture of a SUP paddle. Observations and details were noted during the sessions to create a record of production. Accurate recording of the construction methods is important as it allows identical manufacture of a product to be replicated, or process to be reproduced for a different application. Additionally, these records can aid during an investigation into product failure as they may show the cause of the failure.

The aim of the sessions was to produce a fully functional stand-up paddleboard paddle, produced using composite materials and composite manufacturing methods that are available to niche markets, bespoke and low volume batch production.

Another aim is to consider the health and safety procedures and protocols that were in place for the manufacturing methods and techniques. As well as making sure they are followed during the duration of the construction of the paddle.

To identify the methods used in this production and other techniques that could have been used. Then each should be analysed for suitability for niche market application and low volume manufacture.

2 Research

2.1 Health and Safety

2.1.1 Health and Safety Legislation

Workshop health and safety is wide ranging and of high importance. Every organisation has a 'duty of care' to their employee, this extends to making sure they are trained properly on the machinery, and that the environment is safe for them to work in (HSE, n.d.). Health and safety policies are put together by organisations to manage health and safety concerns, everyday safety and inform people within the organisations of regulations and legislation for current working environment. Regulations cover everything from general moving and working in the workshops to common injuries using certain machinery.

Risk assessments should be carried out for every risk, this allows risks to be known and therefore you can prepare for them and even take controllable and precautionary measures. Specific health and safety concerns for composites are dangerous substances, sharp tools (knives and scissors), slips trips and general safety.

2.1.2 Personal Protection Equipment (PPE) + Health & Safety rule + Everyday Practices

Personal protective equipment is specific to machinery and certain labs and workshops, read relevant signage and policies to know what PPE is required (Tibbot, 2017). Some PPE is organisation wide such as Steel toe capped boots and lab coats, as well as jewellery removed, and long hair tied back. Whilst in the workshop you should behave in a professional, mature and a sensible manner; as part of this food or drink should not be consumed within the workshops.

Before commencing work, be sure to apply barrier cream or gloves to your hands. At the end of each session, soap should be used to remove grease, oil and coolants. A replenishing cream should then be applied to moisturise the hands after cleaning. At the end of every session, it is essential that the workshop areas, any machines and equipment used are thoroughly cleaned.

Other PPE is more specific and is required only on specific machinery; such as safety glasses, dust masks, air fed mask and gloves. This is signalled by the use of signage in different areas and on specific machinery. The same goes for training, machinery in the workshops and labs can be dangerous, certain machinery can be used once training is completed with some machinery needing supervision as an additional precaution. Facilities and specific machinery training are mandatory and documentation of this should be kept.

You should not use machinery or facilities under the influence of drugs, alcohol, medication or suffering with a health condition.

WHY HAS THE
COLOUR SUDDENLY
CHANGED?

3 Methodology

3.1 PPE, Equipment and Tools Required

PPE:

- Dust mask
- Overcoats
- Safety goggles
- Natural blue disposable gloves XL
- Steel-toed safety boots
- Long trousers
- Air fed spray mask

Equipment:

- Airline
- Glass paper 180, 240, 320, 600, 800
- Stanley knife/blade
- Carbon shears
- Spray gun
- Spray booth
- Paper resin cups
- Resin stirrer
- Steel ruler
- Vacuum bases and connectors
- Vacuum pump + hoses
- Autoclave

NARRATIVE ?

3.2 Materials

- PU600 High Density Polyurethane Model Board
- High build primer
- High Gloss
- Wax mould release
- GC50 Epoxy Compatible Clear Polyester Gelcoat
- Chopped strand fibreglass mat
- EL160 High Temp Epoxy Laminating Resin
- EL160 High Temp Epoxy Hardener
- Prepreg carbon fibre
- Steel mandrel
- Release ply
- Peel ply
- Fluffy breather layer
- Self-adhesive vacuum bag putty
- Vacuum bag

3.3 Method

The paddle is to be constructed from three main components; these were the T-handle, Shaft and Blade. Various different methods were used to construct the moulds and components, including different materials. This was done to increase the depth of knowledge and understanding CRFP production and different manufacturing techniques that are suitable.

DIAGRAMS? PICTURES?

3.3.1 T-handle

3.3.1.1 Mould Prep

The T-handle was constructed using a buck or plug method. The plug was originally CNC from high-density PU600 Polyurethane model board then hand finished in order to decrease machine time.

The first finishing process that was undertaken was the sanding of the plug. Every part of the plug was lightly hand sanded with increasingly finer grit of glass paper to remove machining marks and leftover waste material missed by the machining. This was carried out until the plug was smooth.

Then a high build primer was painted on by hand to fill any voids, pits or grooves that are not part of the design and were created during either the machining or sanding processes. There were some scores in the top of the handle created during machining for our particular plug. The layer of primer was then sanded back using the same process as before, with the grit getting finer to give a smooth sleek finish.

A high gloss coating was then applied to the plug with the spray gun. This was carried out in the spray booth with all the necessary PPE. The gun was held 6 to 8 inches from the plug and sprayed over the part in a continuous motion. The gun started off the edge of the plug, by pulling the trigger half in, to start the air supply then fully engaged to release the gloss. The plug was sprayed at all angles that covered all the surfaces that will contact the mould.

Once the coating has dried a hard carnauba wax is rubbed on left to set for a minute or two and then buffed back. The wax was built up in layers, between 3 and 10 layers of wax. This enables the mould to release off of the plug, the preservation of the plug allows for additional moulds to be made, for high quantity manufacture or mould pattern retention for the future.

After the wax is applied to the plug the mould can be built up. The first part of the mould is a gel coat that allows the mould to have a smooth finish (as smooth as the plug is). The GC50 Epoxy Compatible Clear Polyester Gelcoat is brushed on then left to cure for an hour and a half, at which point the coat should be tacky. The resin and chop-strand fibre glass mat can be applied in a ratio of 2:1 (two-parts resin to one-part fibre glass). An EL160 High Temp Epoxy Laminating Resin was mixed with EL160 High Temperature Epoxy Hardener in a ratio of 100:35 (one hundred grams of resin to thirty-five grams of hardener). The resin should be brushed on to the plug, and pieces of fibreglass mat laid on top. Then the mat should be wet out with more resin till it is fully saturated and it conforms to the shape of the plug, brushes and rollers should be used to help the mat conform and remove air bubbles.

Once 10 layers of fibre glass are built-up on the plug they are left to cure in atmospheric pressure and at room temperature. Once cured the mould can be pried off of the plug with wedges, if the plug was properly wax the mould should just pop off with a little bit of persuasion. Any parts of the plug that come with the mould, for example, gloss or primer layers, they should be finely sanded back and then polished up to remove any scratches. Another wax coating can then be put on the mould. The mould was trimmed and split down the middle to allow each side to create a two-part mould.

3.3.1.2 Lay-up

Prepreg material was used in construction of the part. The prepreg was pre-cut into individual plies with pre-set specific fibre orientations as well as fibre placement. The T-handle was laid up with an overlap which will allow the two halves to bond together.

A vacuum bag is placed in the centre of the part and the two halves of the mould lay on top of each other. The internal vacuum bag is inflated, and the mould clamped shut. The mould is then placed in the autoclave and cured for two hours with a ramp of 2.33°C/minutes of 30 minutes (50°C to 120°C). Where it sits at 120°C for 1 hour then ramps down at the same rate. This is determined from material specification and the capability of the mould material.

3.3.2 Shaft

The shaft was constructed using the roll wrapping method. A steel mandrel was taken, which the carbon is wrapped around but to be able to get the carbon off of the mandrel it either needs to be extensively prepped including cleaning, surface finish, polishing and waxing. Alternatively, to enable the shaft to slide straight off the mandrel, 4-5 layers of release film can be wrapped around the mandrel and taped on (the method that was taken forward in this case). The removal of a shaft off of a mandrel can be aided with a hydraulic puller.

The carbon fibre prepreg was then cut off the roll with the carbon shears, then cut down to size with a Stanley knife following a horizontal tow to keep the ply straight and parallel. The carbon is then wrapped tightly around the mandrel four times, then a peel ply is wrapped around to hold the carbon in place and it also improves surface finish. That concludes the laying up of the shaft. All that is left is to vacuum bag the entire mandrel. The bag is sealed at one end and two layers of fluffy laid in, the mandrel is then placed between the fluffy which enables a vacuum to be pulled across the bag. The open end is then sealed by turning the edge inside out and laying the putty along the edge then pressed down from the centre out, till the length is sealed, then a vacuum is pulled to test the bag and it is then placed into the autoclave on the same cycle as previous as the same material was used. No additional pressure was used, this is to prevent the shaft from being pressed to the mandrel.

3.3.3 Blade

The construction of the blade used in this production is a two-part negative mould which is much like the final moulding process of the T-handle (both parts of the mould are negative leaving a cavity). The main difference is the construction of the mould, rather than constructing a composite mould from a plug, the moulds will just be machined from either model board or metal, then finished and waxed. The same curing process was used as the T-handle, as it was the same material. The internal bagging process of the blade was also the same as the T-handle.

4 Discussion + Analysis

4.1 Fabrication Methods

4.1.1 Lay-ups

Different layup methods are used as they suit certain applications or situations. These each have their own advantages and disadvantages. Layup is the process of how the material is laid in the mould.

4.1.1.1 *Wet lay-up (Tibbot, 2019)*

Wet layup was used in the construction of the mould for the T-handle of the paddle. In wet layup, the dry fibres are laid down in the correct orientation and resin is brushed in, to wet out the fibres, ply by ply. Wet layup is an inexpensive method that requires no consumables and no machinery as it can cure at room temperature in out of autoclave operations (OOA). This process contains more resin than is optimal, which increases weight. This process can be improved by placing in an oven which will speed up the cure time, and vacuum bagging debulks and compacts the plies.

4.1.1.2 *Resin Infusion (Tibbot, 2017)*

Resin infusion process lays all dry fibre plies into the mould with peel ply, an infusion mesh, spiral coil tube and silicone vacuum connectors. Which is then all bagged up and a vacuum pulled, then the resin is drawn through into the bag. The spiral tube disperses the resin across the part and the mesh allows it to flow through the part and infuse into the fibres. Extra resin is caught in a vacuum catch pot, the input hose is then clamped, and the pump left to pull out extra resin. As all extra resin is pulled through it means that the part has a more accurate amount of resin and weighs' less than a wet layup alternative. The output hose can be clamped, the pump turned off and the part left to cure. Once again heat from an oven would speed up the curing process.

4.1.1.3 *Prepreg (Tibbot, 2017) (Tibbot, 2019)*

Prepreg composites come as a roll of pre-impregnated fibres which have to be stored in a refrigerator. They require autoclave or hot press like procedures as they need both pressure and heat to cure. Although the laying up process is much simpler as the individual plies are cut into the required shape, size and orientation. They are then laid into the mould, debulked if more than 8 plies are used. Then placed in the hot press or under vacuum and put into the autoclave.

4.1.2 Fabrication Methods

4.1.2.1 *Plug Mould*

Buck or plug mould construction is an inexpensive mould creation technique and can be done with little machinery and allows moulds to be created over an original part and replicate it with composite construction. Plug creation reduces computational time as CAD and CAM models do not need to be altered or reversed like conventional mould and tool creation. Original componentry can be used as a plug, to create the mould around. (Tibbot, 2019)

4.1.2.2 *Single Moulds*

Single part open moulds work well with all types of lay-ups, the use of vacuum bagging allows the composite to be pressed into a negative mould or wrapped over a positive of a mould. These positive and negative moulds can be constructed from a plug or created conventionally. Single part moulds offer a simple solution for non-complex parts, although they only give one good surface finish. (CompositesWorld, 2016)

4.1.2.3 *Roll Wrapping + Filament Winding*

Roll wrapping is the process of wrapping composites around a mandrel. Works best for tubes smaller than 150mm (CompositesWorld, 2016). Filament winding is similar as it is also the process of

wrapping composites around a mandrel, the differences being that tube rolling wraps a woven fibre ply around the mandrel. Whereas, filament winding winds a single filament (tow) around a mandrel. Filament winding is an automated process and uses a robotic arm to move either the mandrel or robotic filament feeding head. This gives it greater application, for more complex geometry such as pressure vessels. Mandrels can be left in the part as a core, depending on the material and application, the disadvantages normally out way the benefits of this. Single piece mandrels are typically removed with the use of a hydraulic mandrel extractor, the mandrels are either highly finished or wrapped with release film, tapered mandrel allow for easier extraction. Other mandrels are either dissolvable or collapsible, the dissolvable mandrels are dissolved with a solvent then washed out and collapsible mandrels are made from many pieces which come apart and be removed from the part. (Tibbot, 2019) (CompositesWorld, 2016)

4.1.2.4 Two-part Mould

Two-part mould works well in the hot press with a positive and a negative part of the mould which fit together, this mould type has an increased surface finish and good pressure on the component. A negative and negative mould used in the T-handle and blade of the SUP paddle, as before surface finish is good it allows for cores as well as internal pressurised bagging in the autoclave. This process works well with all types of lay ups.

4.1.2.5 Additive Manufacture + Injection Moulding

Additive manufacture and injection moulding can both be used as composite manufacturing methods traditionally both used for plastic production. Chopped fibre reinforcements are mixed in and produced using the same as if it was a plastic. The fibre reinforcements are compromised in comparison to more traditional composite methods but superior to conventional plastic production in terms of physical prosperities not economical factors as composites are harder to recycle and both methods suffer more from ware on machinery due to the process of the chopped fibres rubbing past it. These both have high initial machinery costs as well as tooling costs for injection mould which do suit low volume production.

5 Conclusions

This conclusion evaluates the use of composite in low volume, small batch and bespoke productions in the Extreme Sports Industry. I believe composites can be advantageous to the niche market that is Extreme Sports. Although, due to the numerous composite fabrication methods for producing the same component, each with their individual drawbacks and benefits, the use of composites within this industry for low volume production is based on the application. With that said, from the evaluation of different techniques, I found that resin infusion method is the most suitable for low volume production as it is inexpensive and requires little machinery and some consumables. In comparison to prepreg where autoclaves or hot presses are required. Infusion gives you a much closer resin to fibre reinforcement ratio in comparison with wet layup. The mould used is very application dependent as each process has different positives and negatives.

The SUP paddle was constructed using different construction techniques. The technical report follows the processes involved in the construction of the paddle.

6 References

CompositesWorld, 2016. *Fabrication methods*. [Online]

Available at: <https://www.compositesworld.com/articles/fabrication-methods>

[Accessed 10 11 2019].

Cytec Engineered Materials , 2012. www.cytec.com. [Online]

Available at: http://www.cytec.com/sites/default/files/datasheets/CYCOM_2020_032712.pdf

[Accessed 10 4 2016].

HSE, n.d. *Health and safety made simple*. [Online]

Available at: <https://www.hse.gov.uk/simple-health-safety/index.htm>

[Accessed 10 11 2019].

Tibbot, A., 2017. *Health and Safety Guidelines*. Swansea: UWTSO.

Tibbot, A., 2019. *Composite Production Techniques* [Interview] (20 11 2019).

EXPAND

LIMITED
DETAILS

SOI.

DETAILS OF INDUSTRIES
THAT USE PROCESSES?